Mineral Potential of Eritrea, and Fe-Oxide and Sericite alteration mapping using the Remote Sensing and GIS Techniques

An Internship program in Japan Space Systems

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Background

- **Bachelor of science in Geology, Asmara University**
- **Exploration Geologist, Department of Mines, Ministry of Energy and Mines**
  - **Secondment Geologist in different foreign, junior and senior exploration companies within Eritrea**
- **Master of Science in Environmental Geology, Shimane University (ABE Initiative scholarship)**

Contents

1. Mineral Potential of Eritrea

1.1 Introduction

- ✓ Located in East Africa
- ✓ Area: 124,000sq.km Land, 55,000sq.km. territorial water and 350 big and small Islands
- ✓ Independence: May 24, 1991
- ✓ Population: 5,000,000; 9 ethnic groups
- ✓ Language:
  - ➢ Tigrinya and Tigre,
  - ➢ Arabic
  - ➢ English

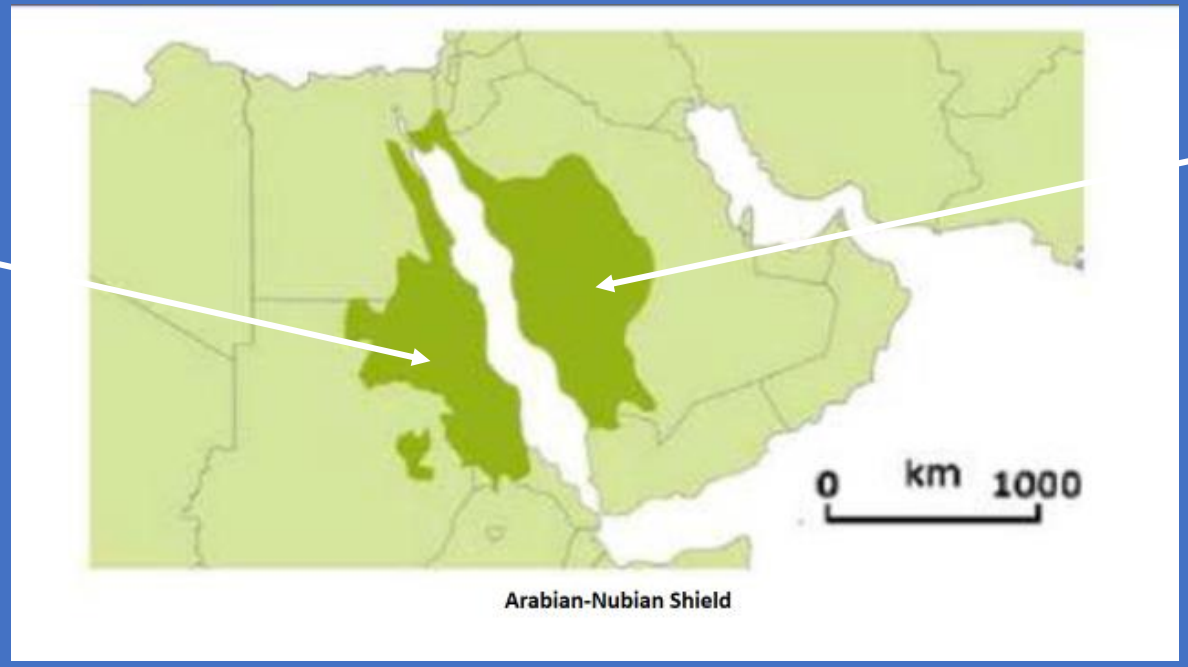
1.2 Geological Setting

4.1 Reginal Geology

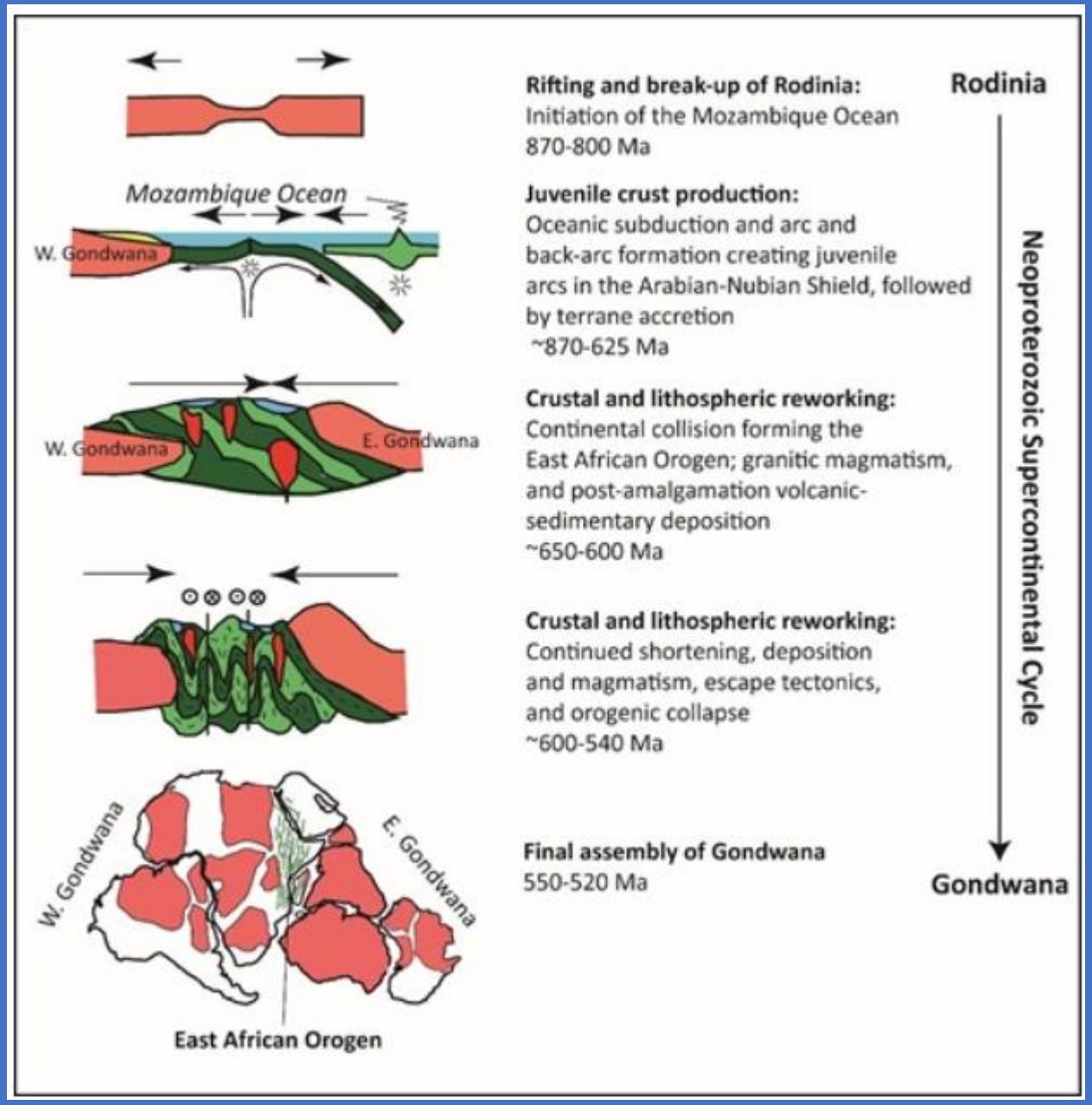
- **Regionally Eritrea is part of the Arabian Nubian shield:**

Lies on the Northern part of the Neoprotrerozoic East Africa Oregen (stern, 1994 cited in (Drury & DE Souza Filho, 1998)

- **The shield was formed by the collusion between the East and west Gondwana upon the closure of the Mozambique Ocean during the Neoproterozoic Pan-African orogenic cycle (Ca. 900-550) (stern, 2008), (Zhao, et al., 2019).**



1.3 Model for Arabian Nubian Shield Formation



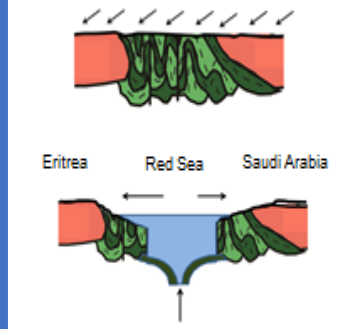
Rifting and break-up of Rodinia:
Initiation of the Mozambique Ocean
870-800 Ma

Juvenile crust production:
Oceanic subduction and arc and back-arc formation creating juvenile arcs in the Arabian-Nubian Shield, followed by terrane accretion
~870-625 Ma

Crustal and lithospheric reworking:
Continental collision forming the East African Orogen; granitic magmatism, and post-amalgamation volcanic-sedimentary deposition
~650-600 Ma

Crustal and lithospheric reworking:
Continued shortening, deposition and magmatism, escape tectonics, and orogenic collapse
~600-540 Ma

Final assembly of Gondwana
550-520 Ma



Peneplain event (post 532MA)
Removed 2km of ANS

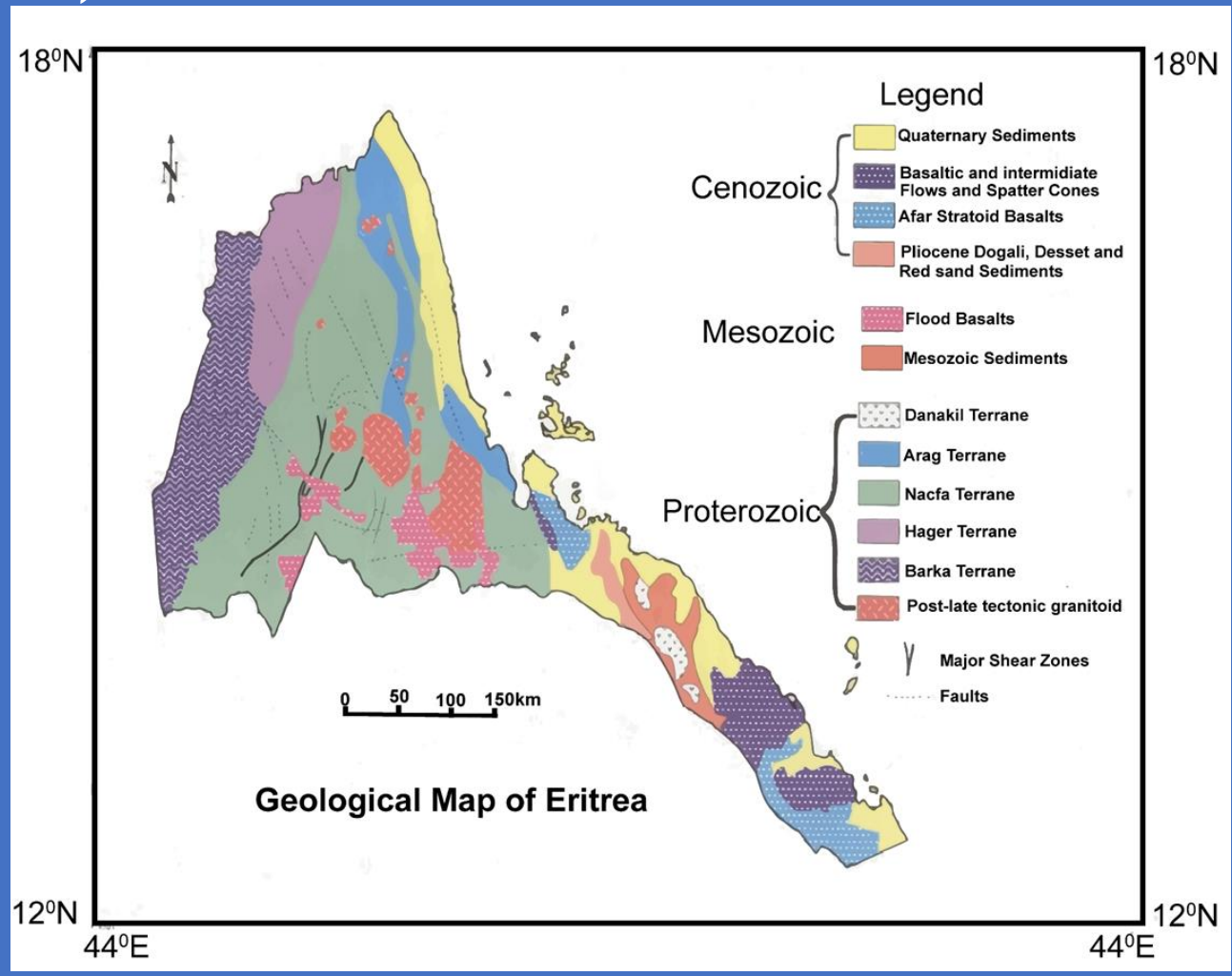
Red sea rifting (30MA – present)

Formation of Arabian Nubian Shield (Peter Johnson, 2010),
Erosion and rifting of Arabian Nubian Shield (Alasdair Smith 2017)

1.4 Geology of Eritrea

- The Neoproterozoic rock of Eritrea is divided into four lithological distinct terranes, each of which extends N-S and are separated by tectonic boundaries (Drury & DE Souza Filho, 1998)
- The terranes are

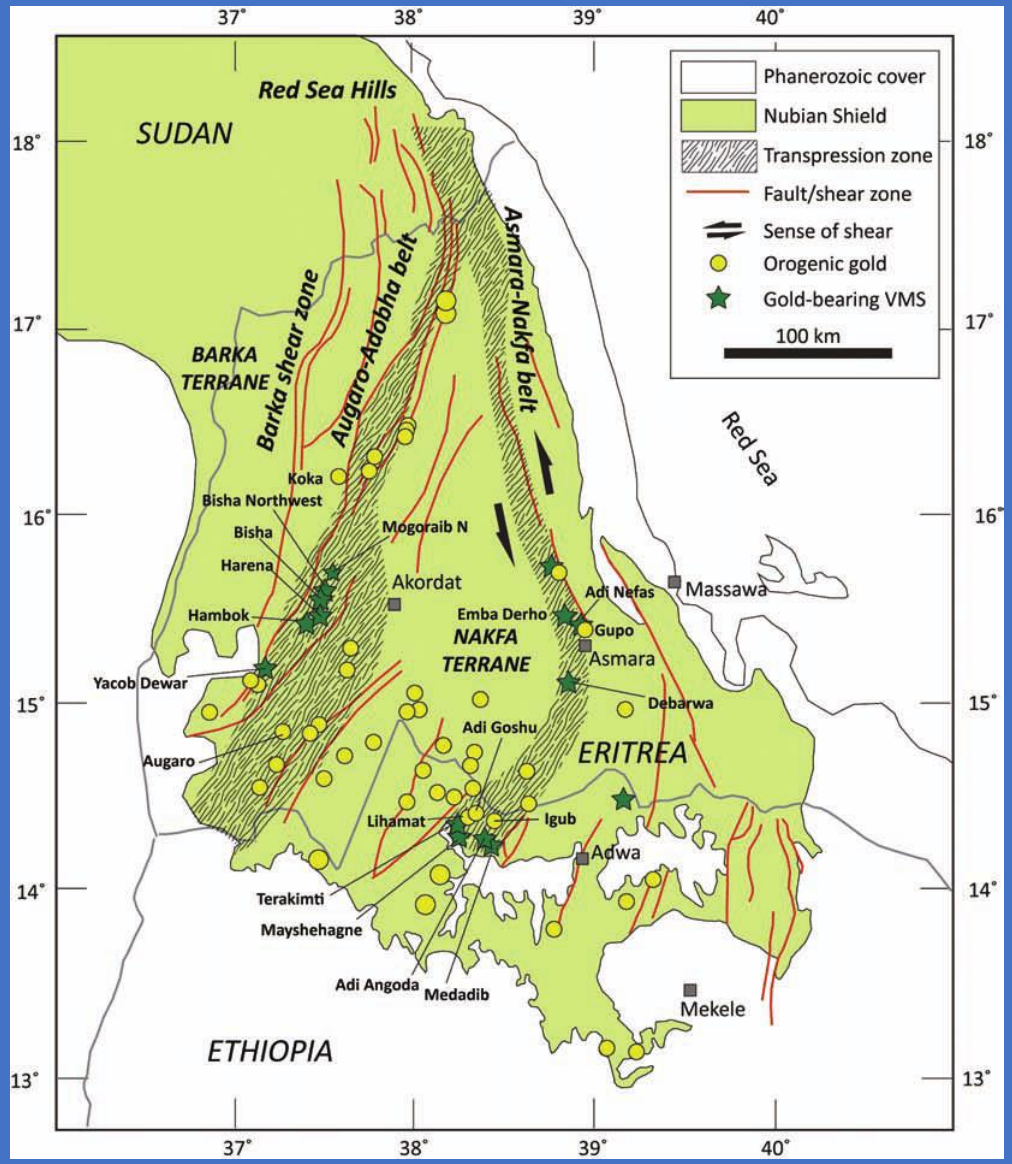
1. Barka Terrane (BT),
2. Hager Terrane (HT),
3. Nakfa Terrane (NT),
4. Arag Terrane (AT)



1.5 Mineral occurrence

Mineralization is associated with the Shear zones, mainly the VMS and the Orogenic gold mineralizations.

- **Base Metals: Cu, Zn, Pb**
- **Precious Metal: Au, Ag**
- **Ni, Cr, Pt (PGE)**

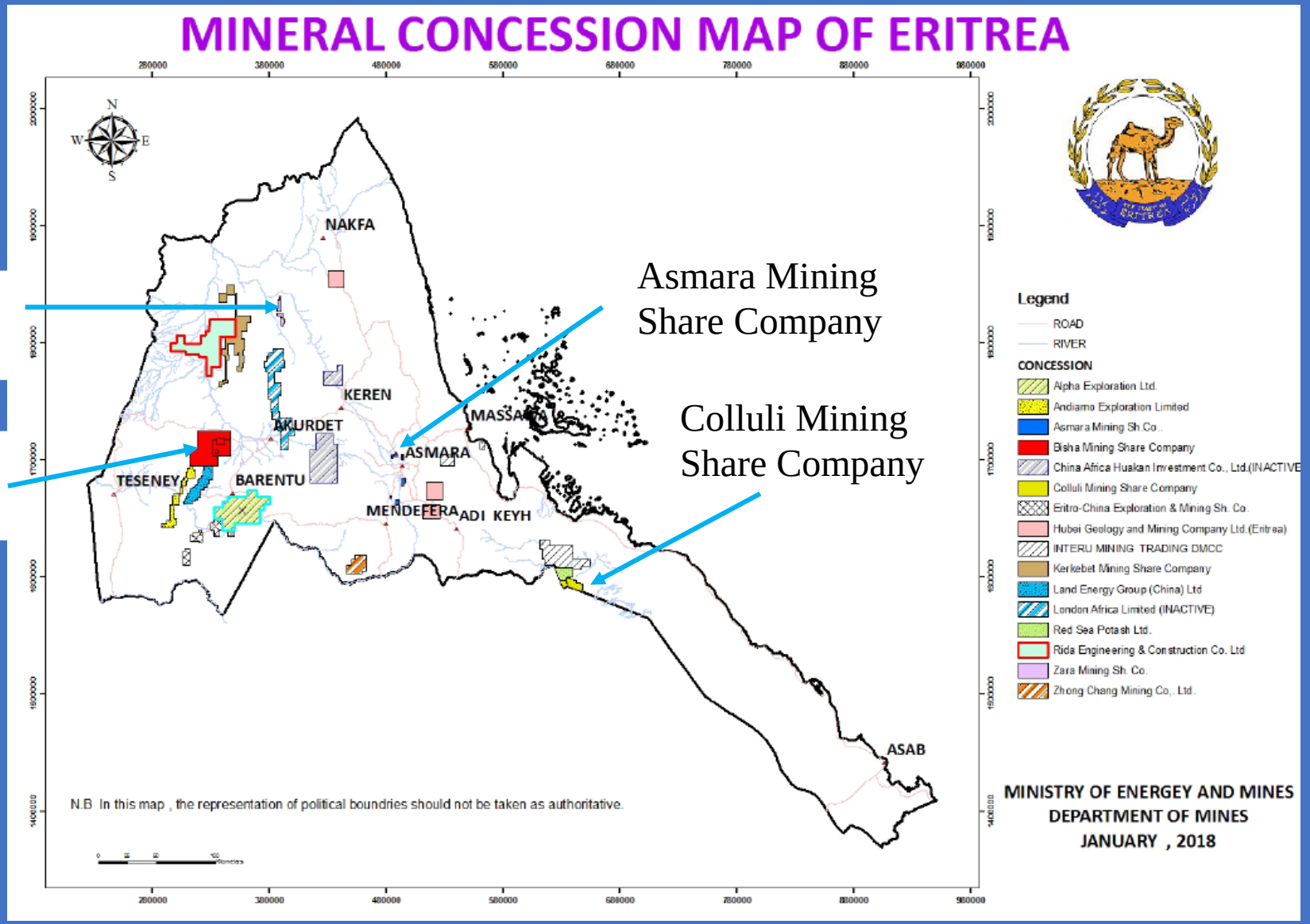


VMS and Orogenic gold mineralization belts (Johnson, et al., 2017; Alasdair, 2020)

1.6 Mining activities in Eritrea

Zara Mine
Share Company

Bisha Mine
Share Company



1.7 Active and developmental stage mines

- **Mining Operations**

Bisha Mining Share Company: (607,666oz gold), (34.1moz silver), (552mlb copper), (2,582mlb zinc) (Alasdair, 2018).

Zara Mining Share Company: (0.76moz @5.1g/t gold) (Alasdair, 2018). The gold is hosted within the quartz stock works in a microgranite lensoid body the mineralized zone has a strike length of 650m.

- **Developmental Stage**

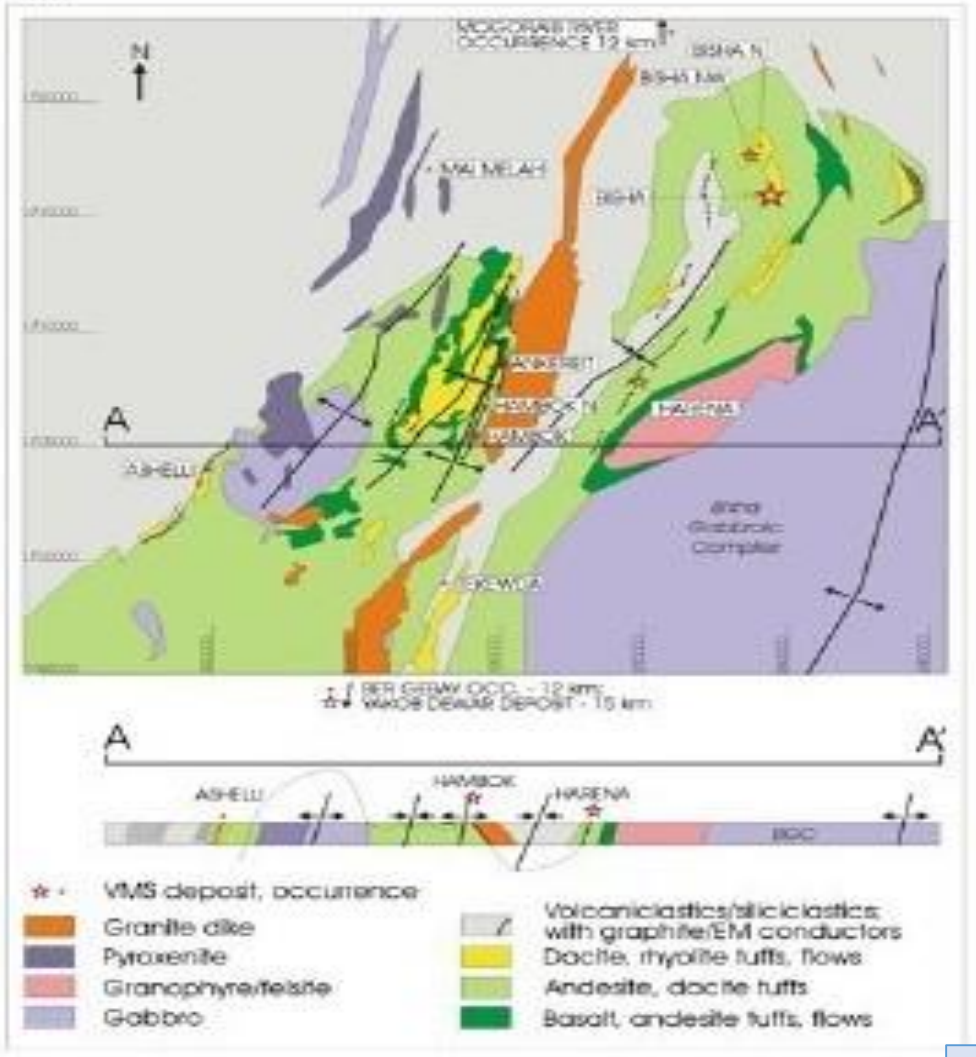
Asmara Mining Share Company: (1,130,000t of Zinc), (580,000t of Copper), (415,000 ozs of Gold and (11moz of Silver) (Alasdair, 2018).

Colluli Mining Share Company: (1,289Bt), with average grade of 11% K_2O, containing 206Mt of SOP (potassium sulphate).

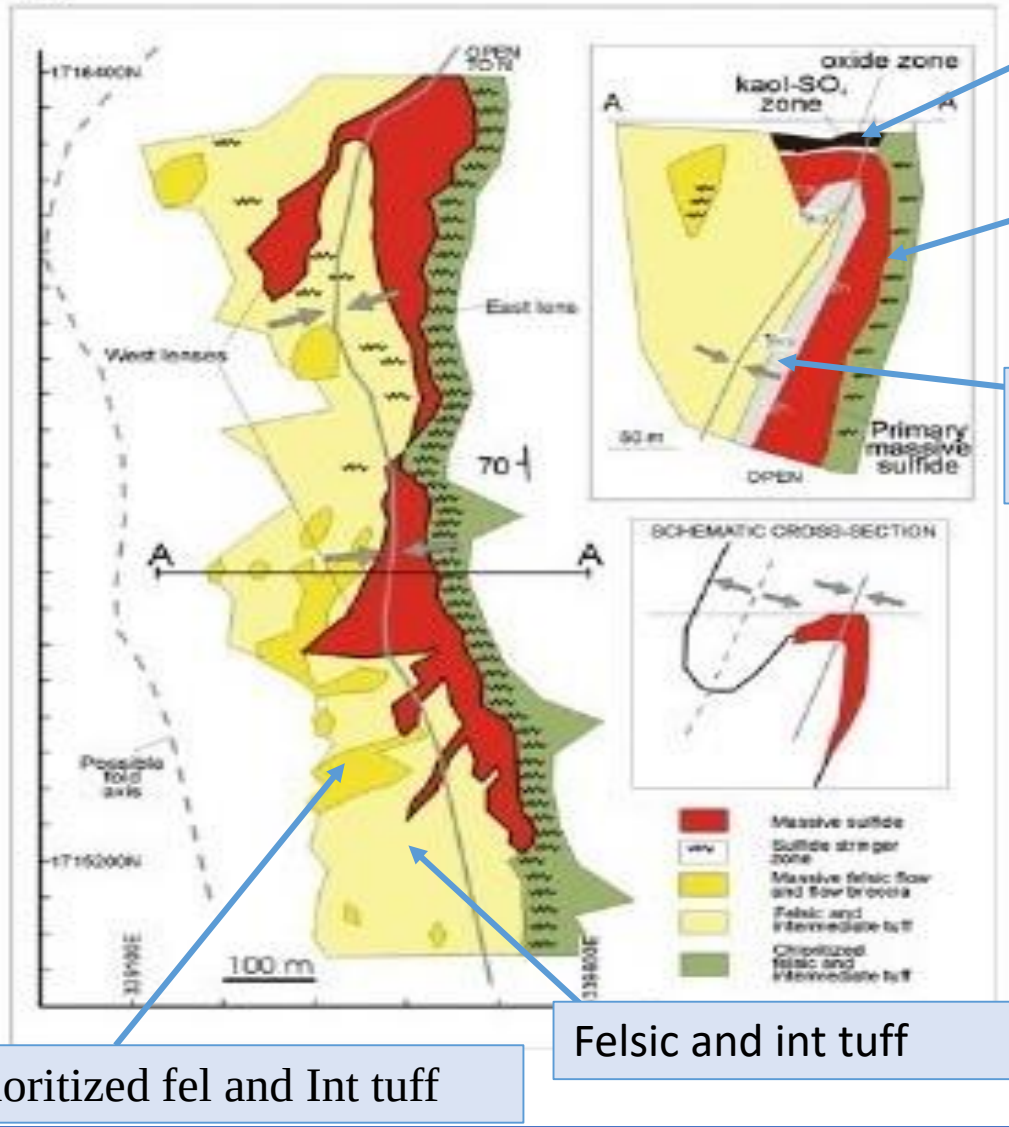
1.8 Geology of Bisha VMS

- The Bisha deposits are located within the Arabian-Nubian Shield. The Arabian-Nubian Shield has a wide range of deposit types and settings, including volcanic massive sulphide (VMS) deposits.
- The rocks are a collage of volcanic arcs, granitoid intrusions, volcano-sedimentary basins, and shear zones.
- It is overturned fold VMS deposit, the west to east and the antiform were eroded where as the synform persists.
- Hosted by Felsic and intermediate tuffs
- 70m thick oxide gossan, diping 60^0 to 70^0 W 1200m along strike

(a) **Bisha geological map**



(b) **Bisha VMS cross section**



Oxide zone

Masssive sulfide

Stringer zone

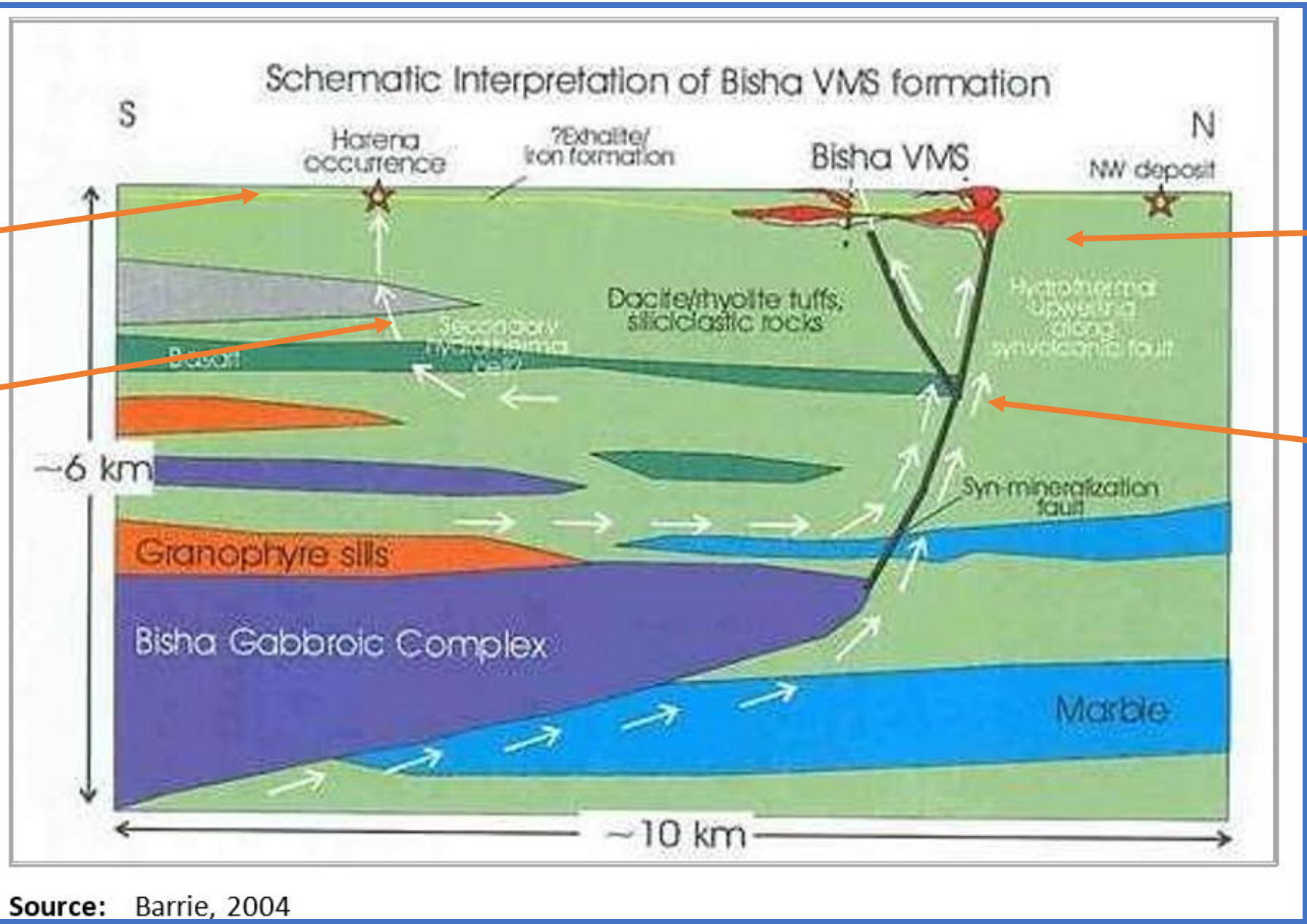
Felsic and int tuff

Chloritized fel and Int tuff

1.9 Bisha Bimodal Siliciclastic VMS Model Schematic

Exhalite / iron formation

Secondary Hydrotherm



Source: Barrie, 2004

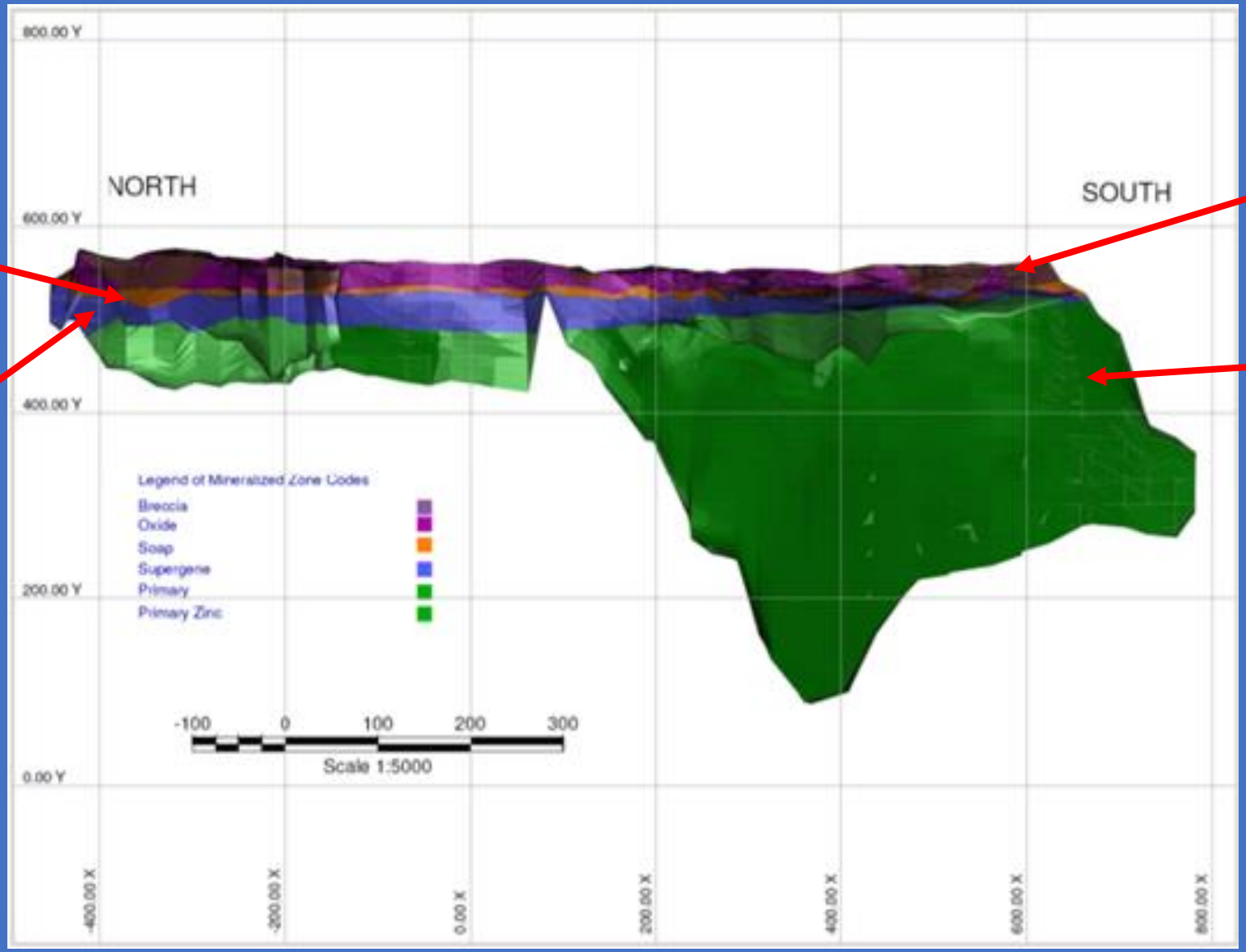
Dacite / rhyolite tuffs, siliciclastic rocks

Hydrothermal Upwelling along synvolcanic fault

1.10 Bisha volcanogenic massive sulphide N-S section

Soap Zone

Supergene Zone

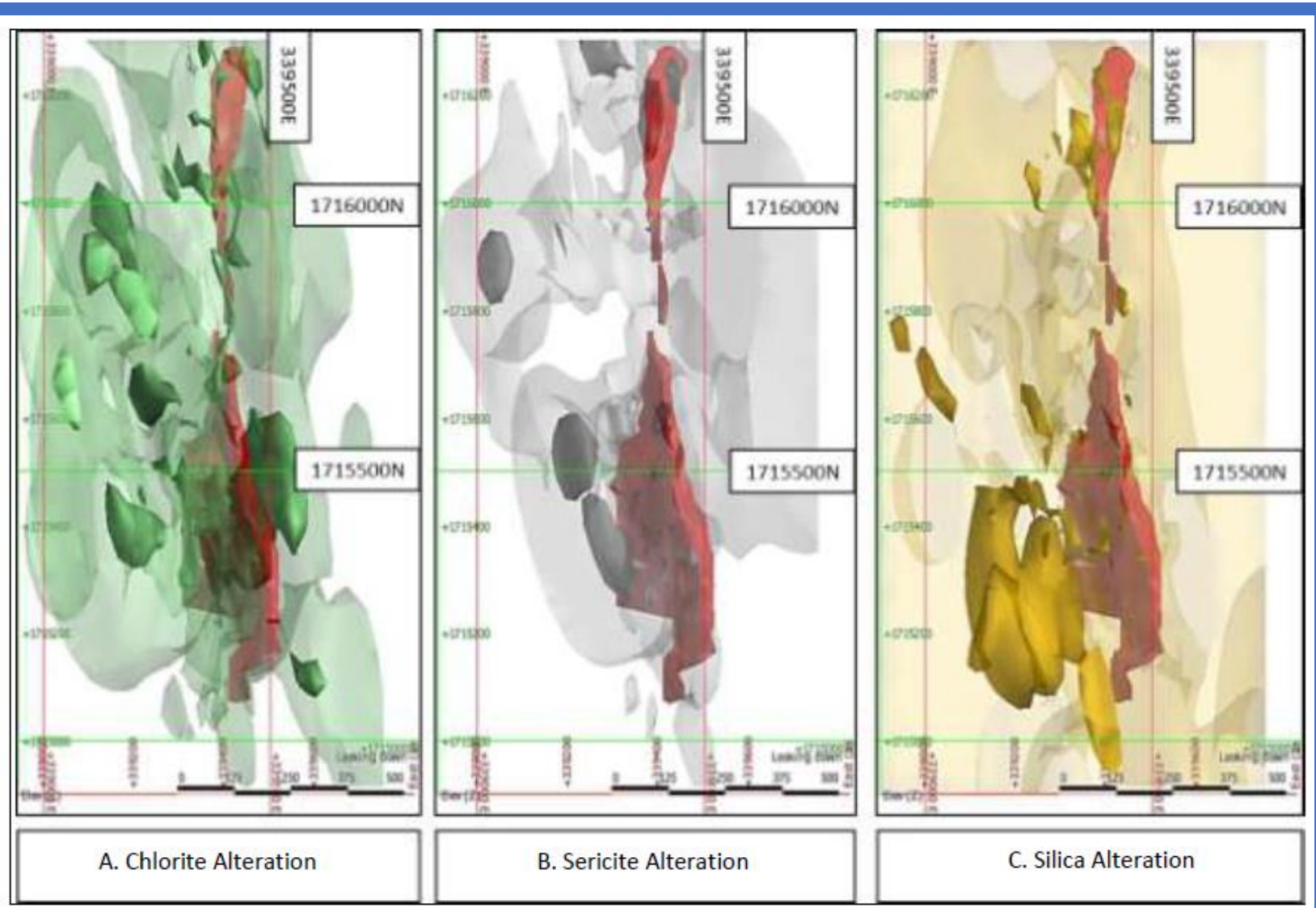


Oxide Zone

Primary Zone

Bisha technical report 2014.

1.11 Bisha deposit alteration patterns



Note: Bisha massive sulphides (red) and alteration patterns for A) chlorite, B) sericite and C) silica. Lighter shades indicate moderate, and darker shades indicate strong/intense alteration. Modelling is based on extracting alteration codes taken from drill logs, and using Leapfrog software to create the alteration distribution patterns.

Nevsun technical report 2014

2. Fe-Oxide and Sericite alteration using the Remote sensing and QGIS techniques (Airborne Spectral Thematic Emission and Reflection Radiation, Aster)

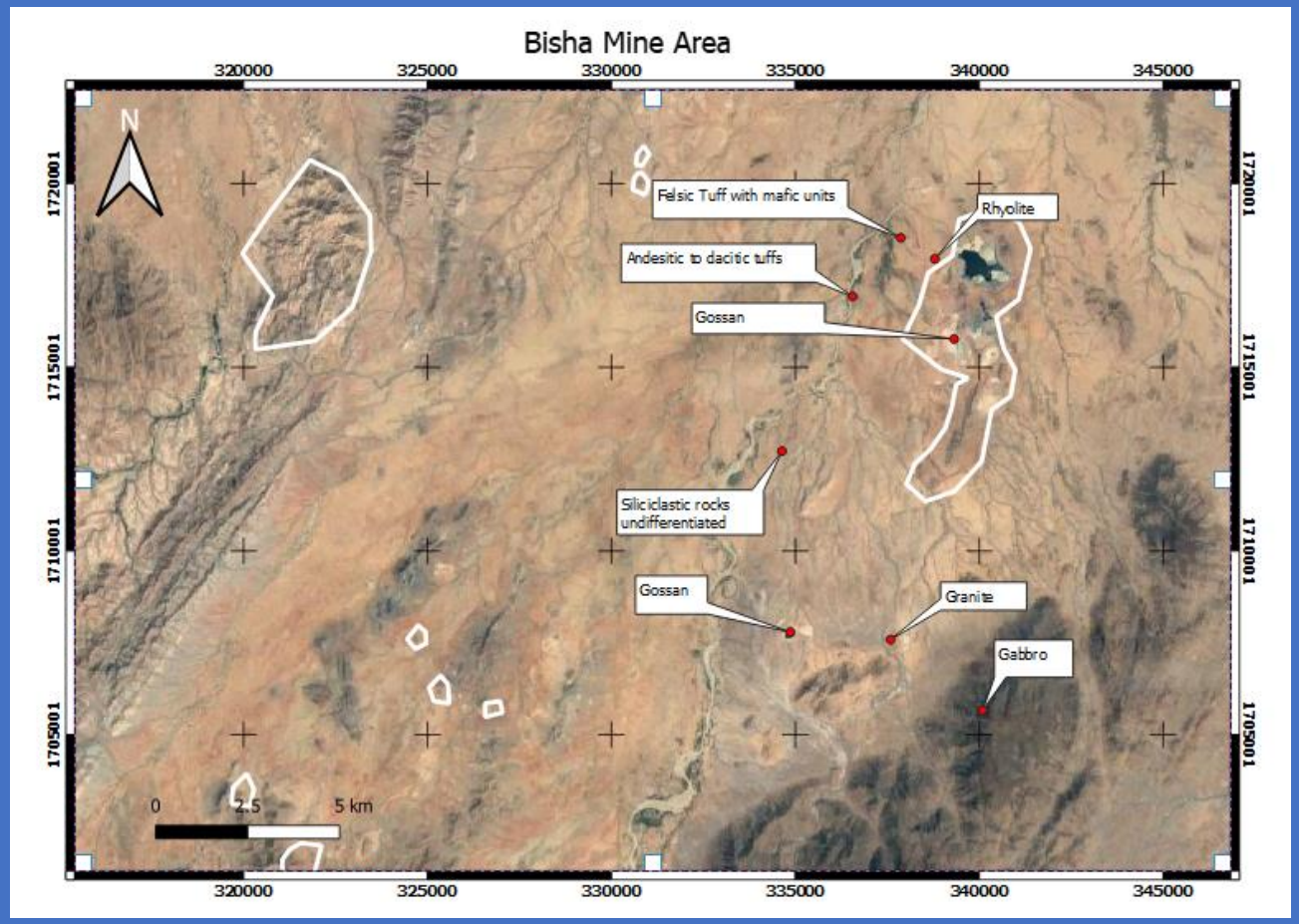
2.1 Downloading Satellite images and Digital elevation model

Methodology

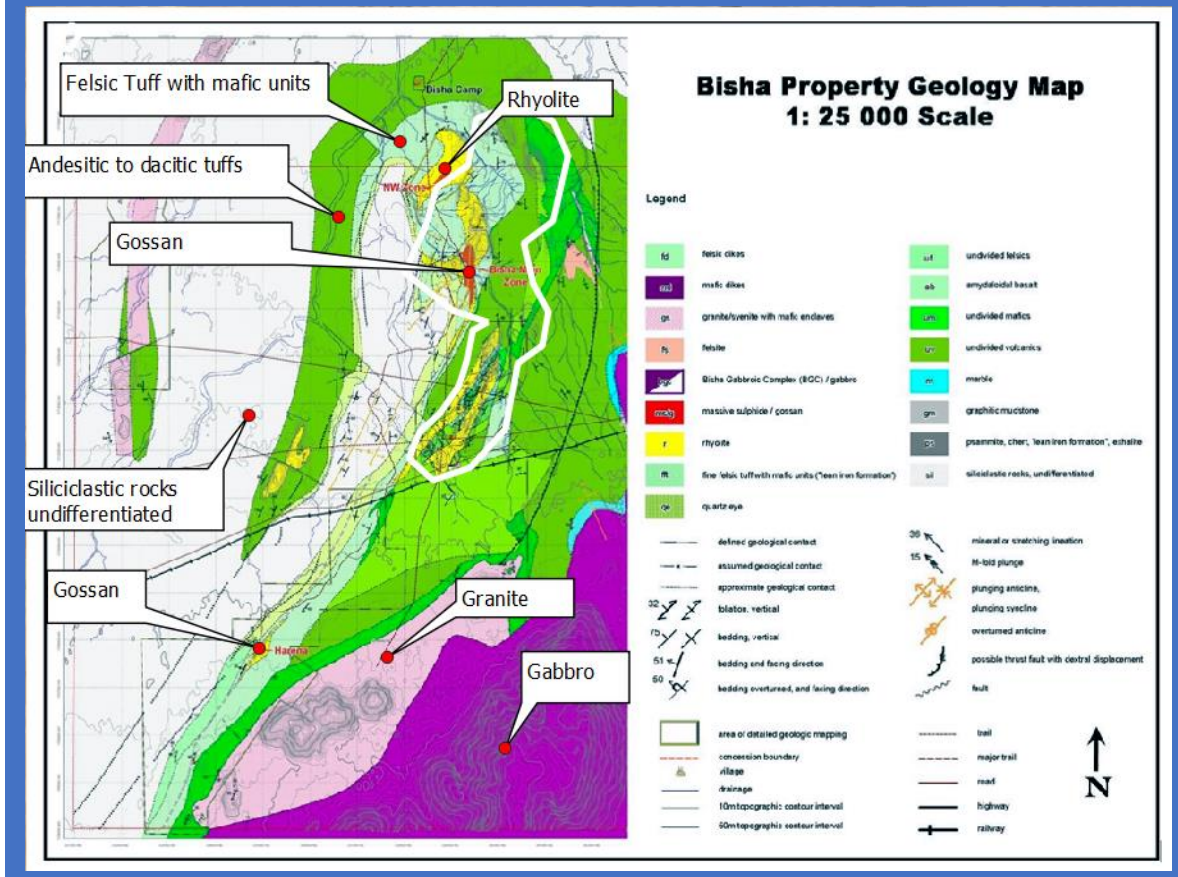
- **SRTM from USGS**
- **QGIS data analysis**
- **DIVA GIS for Spatial administrative data**
- **Aster image from MADAS**

- **Extacting files using the 7 zip and processing in QGIS 3.4**

2.2 Bisha Mine Area gossan, and geological map



Bisha Mine from google earth image

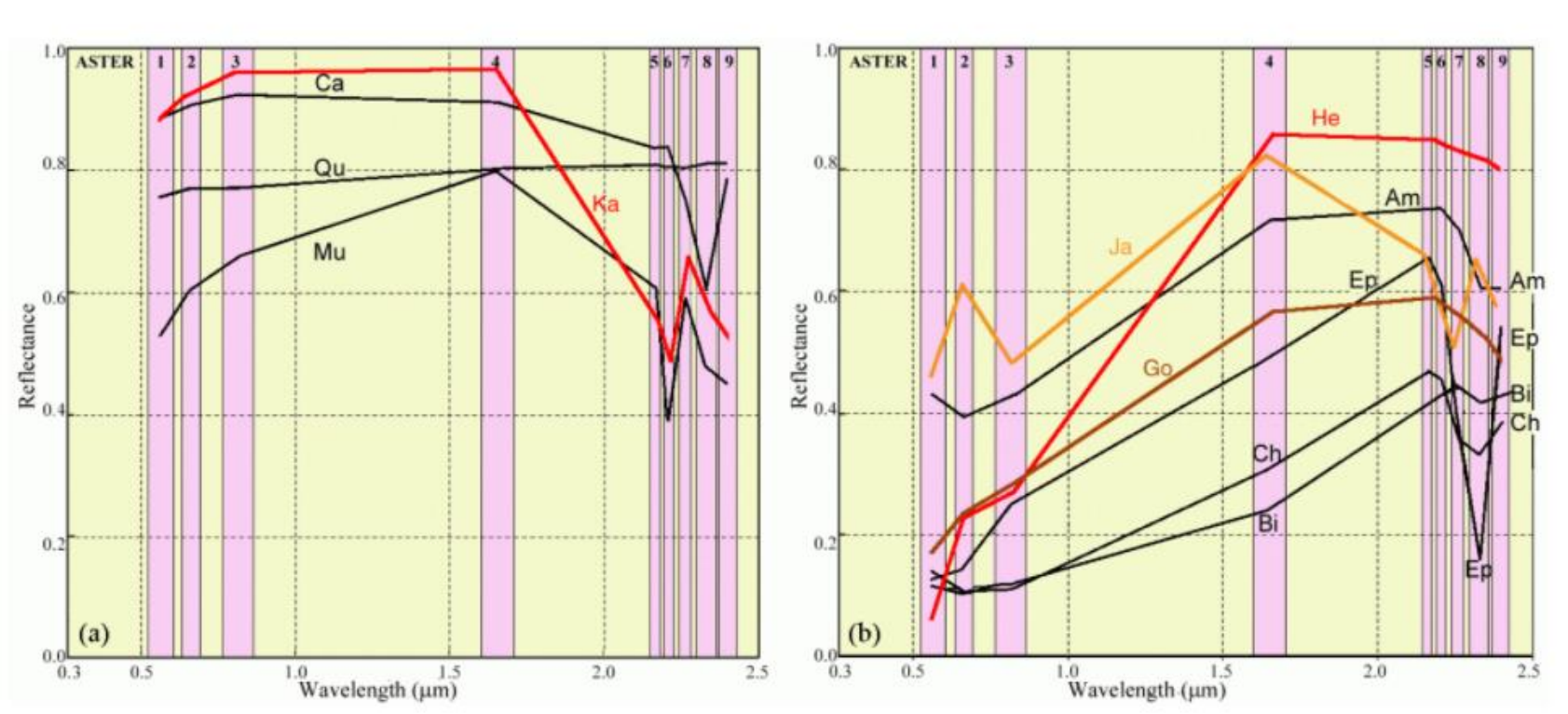


Bisha geological map

2.3 Fe-Oxide Minerals Reflectance and Band Combination

Normal RGB false color image (VNIR and SWIR)

✓Fe-oxide the band rationing 6 is red gossan, 3 green vegetation and 1 is blue the host rocks (Masoud, et al., 2014).



Source from the internet

2.4 Bisha Mine Fe-Oxide alteration mapping

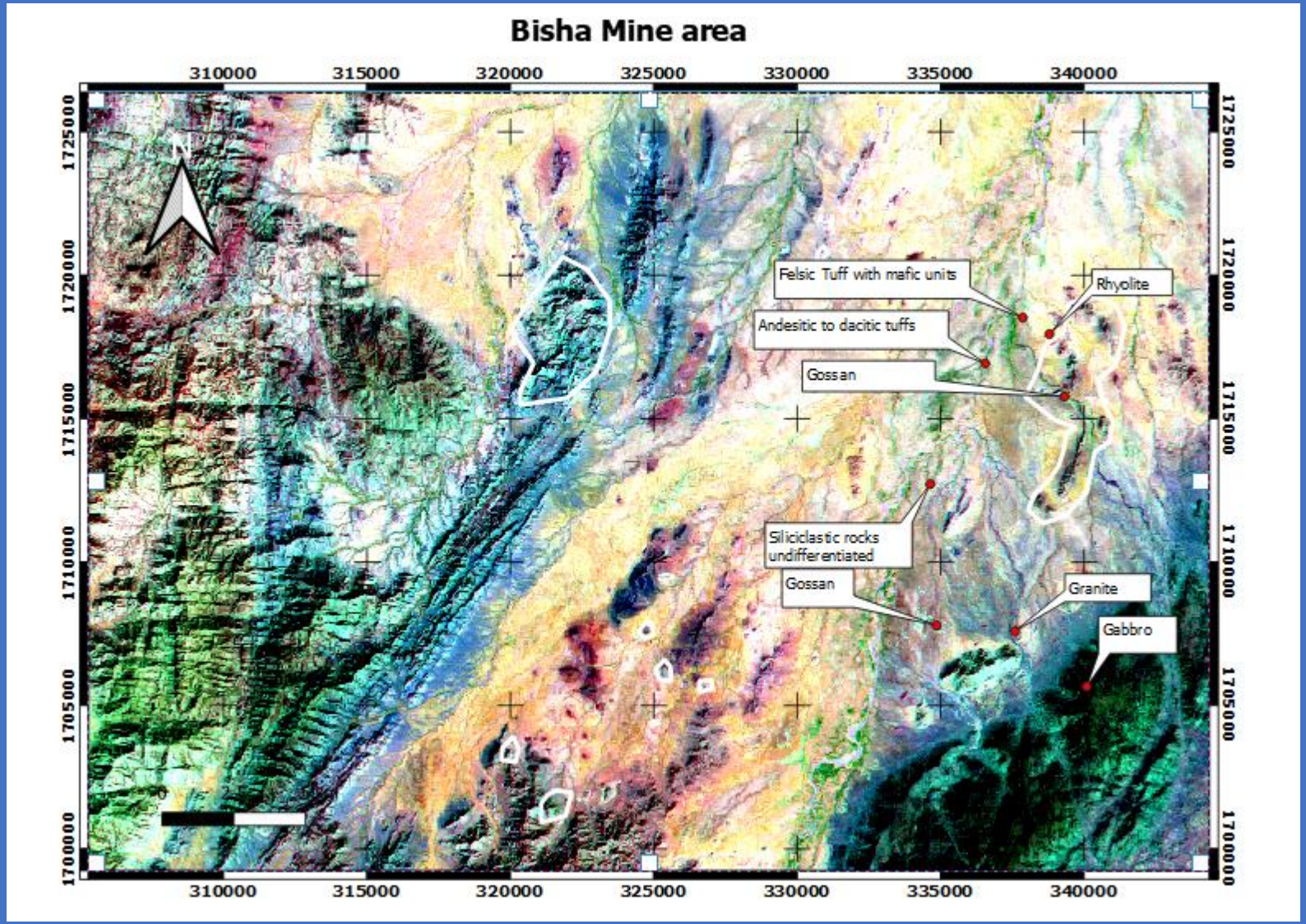
Aster image band RGB (631)

Green is Vegetation

Red is Fe- Oxide

Dark colours are chlorites (Gabbro and Basalts)

Light white to yellow are kaolinite (Felsics)



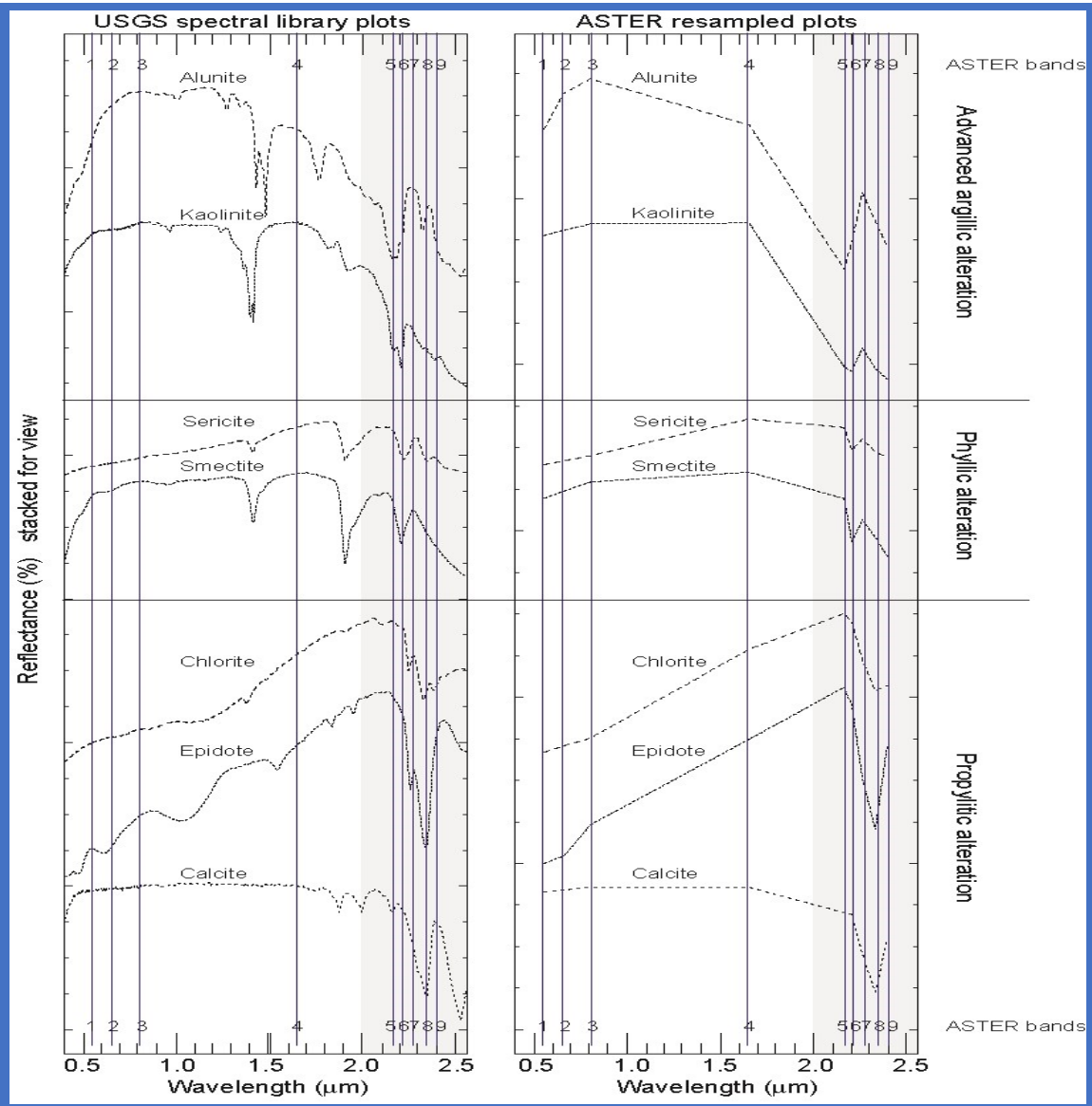
2.5 Phyllic Minerals Reflectance and Band Rationing

Band Rationng (SWIR)

✓The sericite alteration band rationing of (RGB=4/6:5/6:5/8), 4/6 is argillic alteration, 5/6 is phyllic alteration and 5/8 is propylitic alteration (Yojima, 2014).

The argillic alterations are the kaolinite, smectite and illite; the phyllic alterations are assemblages of quart-sericite-pyrite; and the propylitic alterations are the Fe and Mg bearing hydrothermal fluids altering the biotite or amphibole to epidote-chlorite-albite alterations.

The band reflectance and absorption of sericite and kaolinite are indicated in the Figure.



spectral reflectance and ASTER simulated spectral patterns of alteration (Yojima, 2014).

2.6 Aster Band Rationing (4/6,5/6,5/8) For the whole country

Procedures

Downloading Aster image

(from 2000-2008 duration)

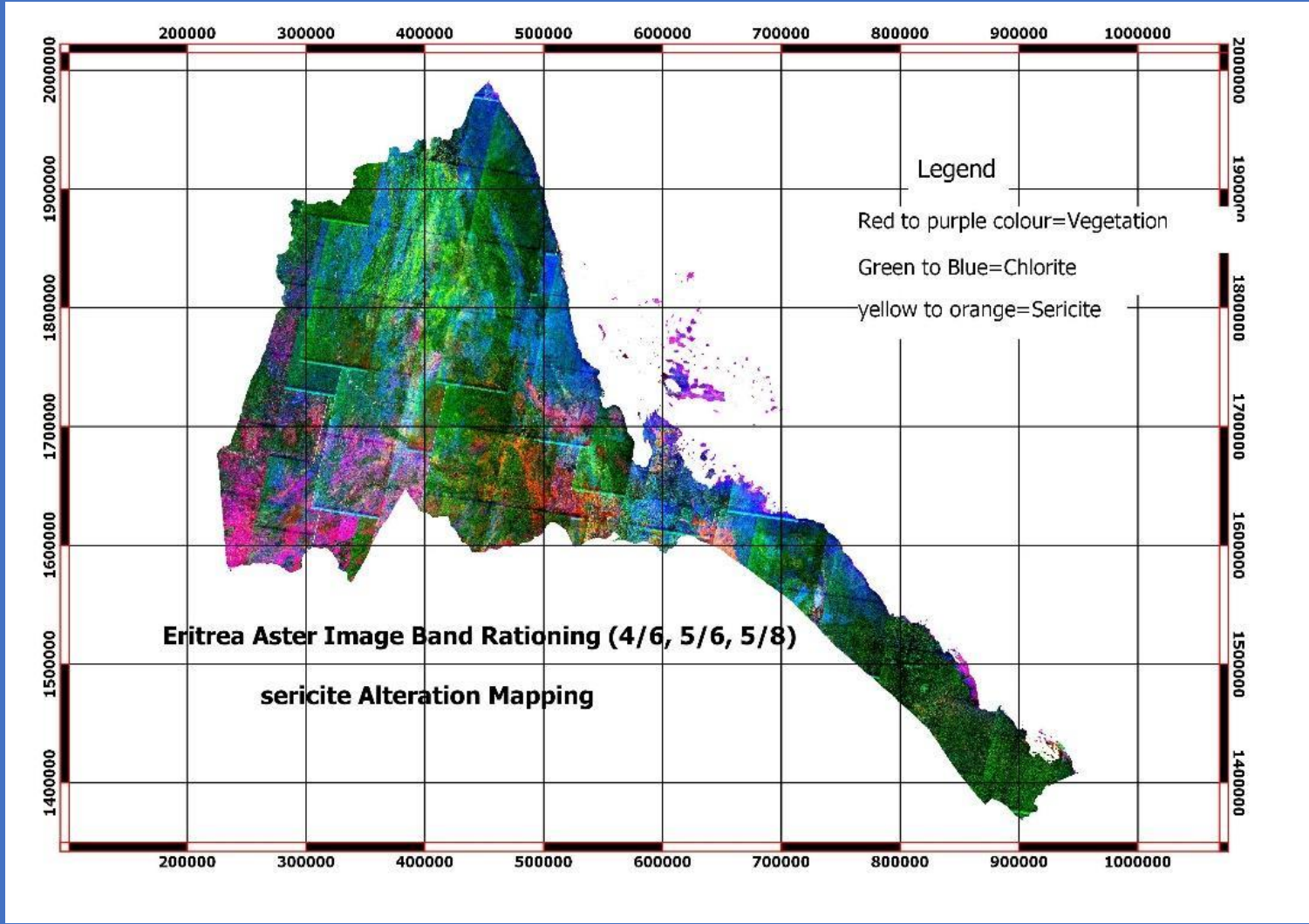
Extracting files using 7 zip

Raster calculator

Virtual raster building

Merging

Clipping raster



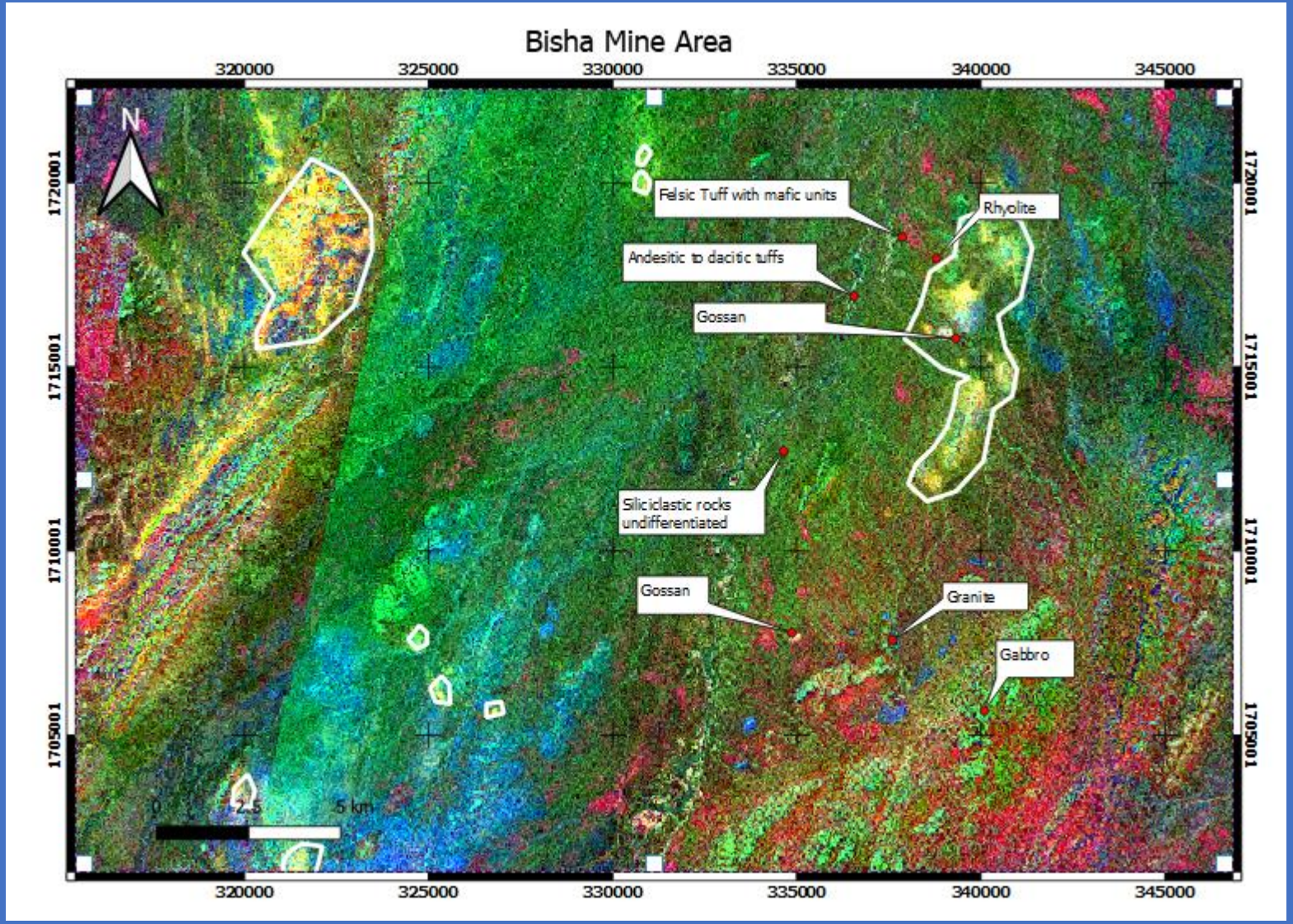
2.7 Bisha Main and Harena area Sericite alteration mapping

Aster image Band Rationing (4/6, 5/6, 5/8)

Red is vegetation

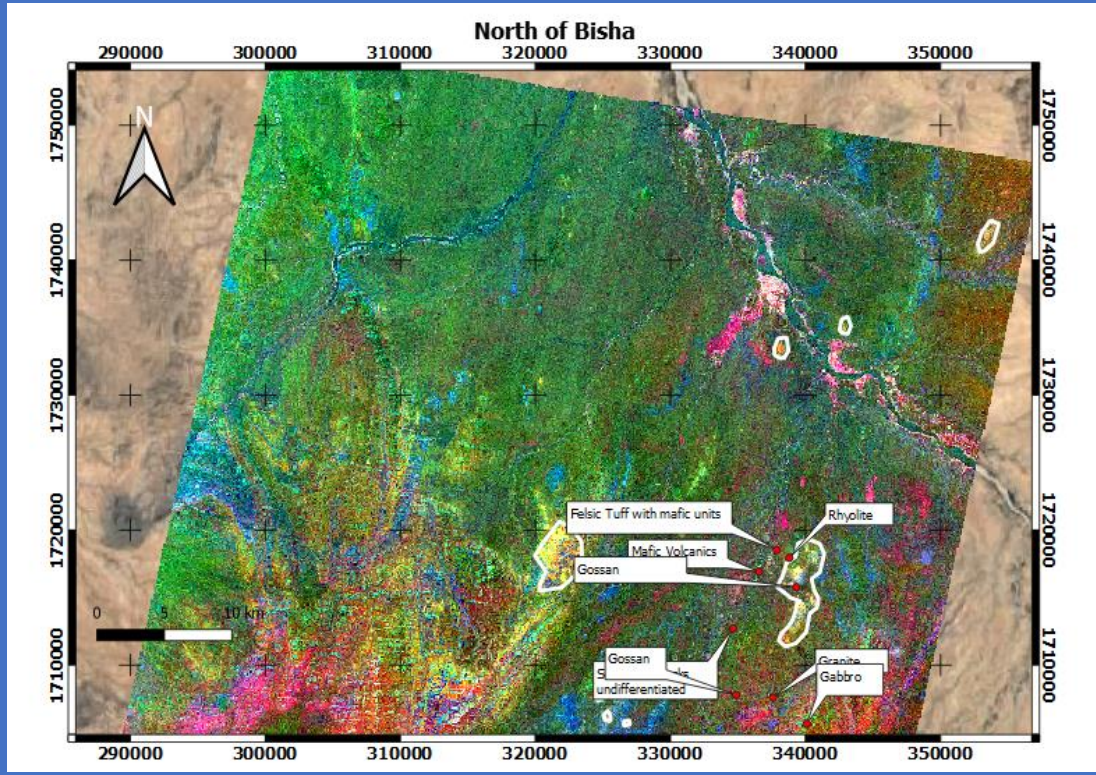
Green to Blue is Chlorite

Yellow is Sericite

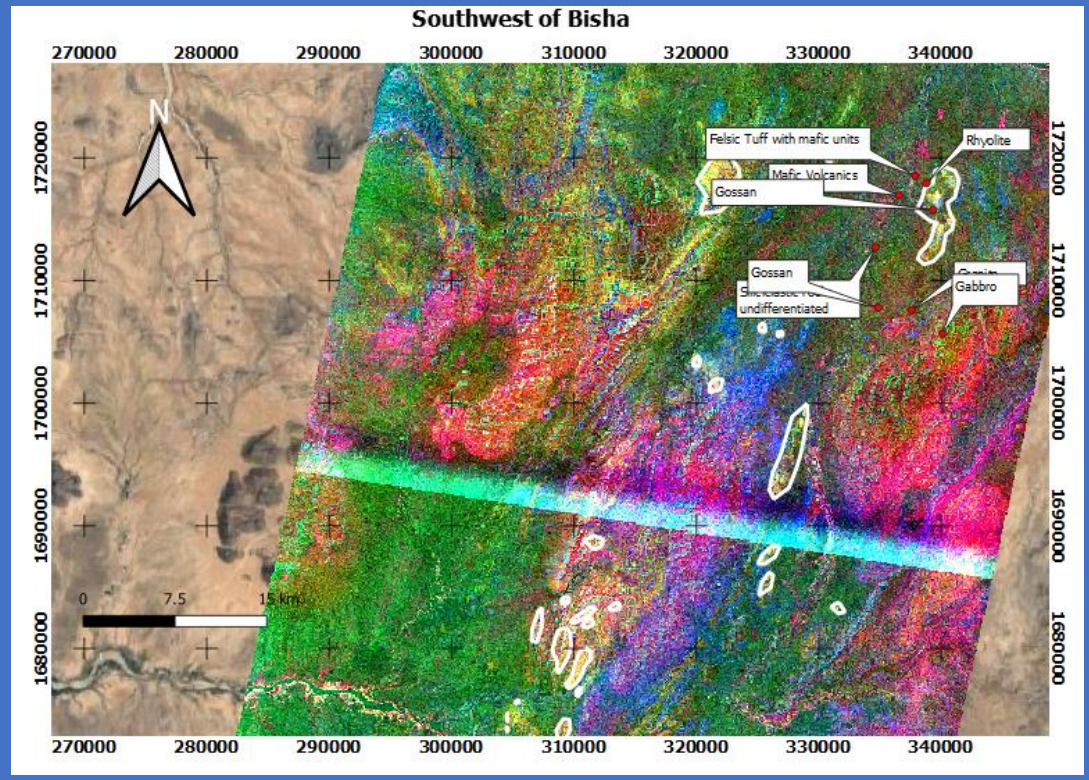


2.8 North and South of Bisha Identified Targets

Sericite alteration zones, Aster band (4/6, 5/6,5/8)

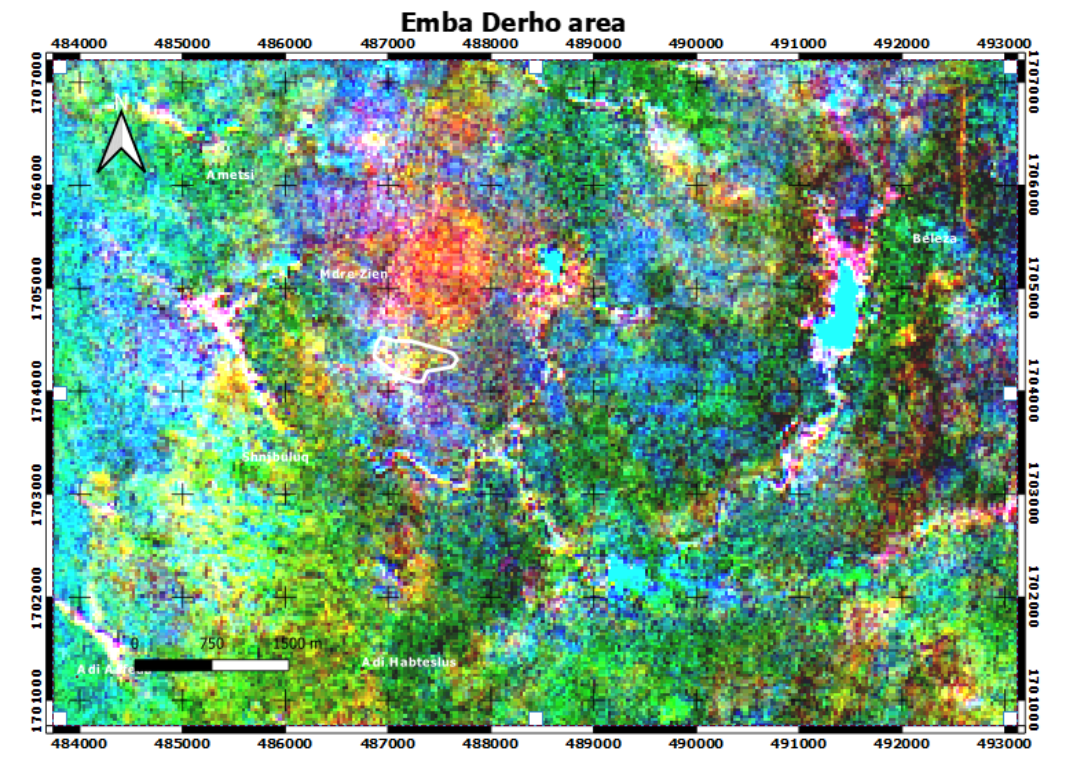


North of Bisha

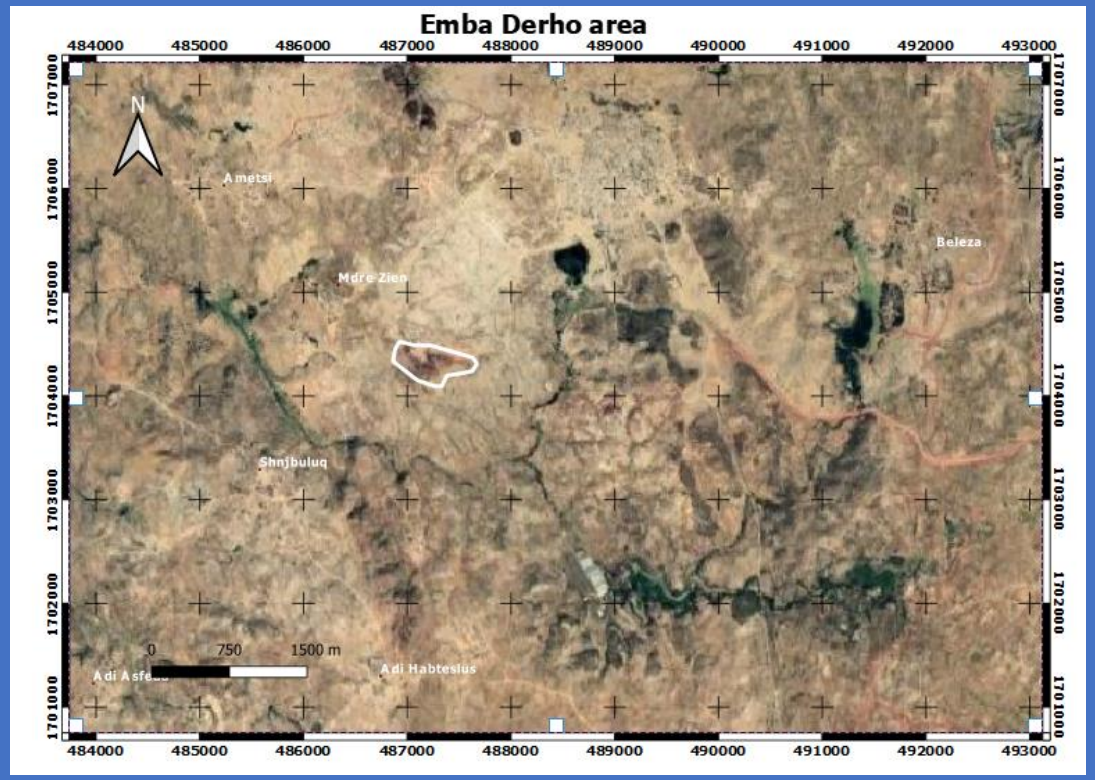


South of Biha

2.9 Emba Derho VMS Mineralizations area

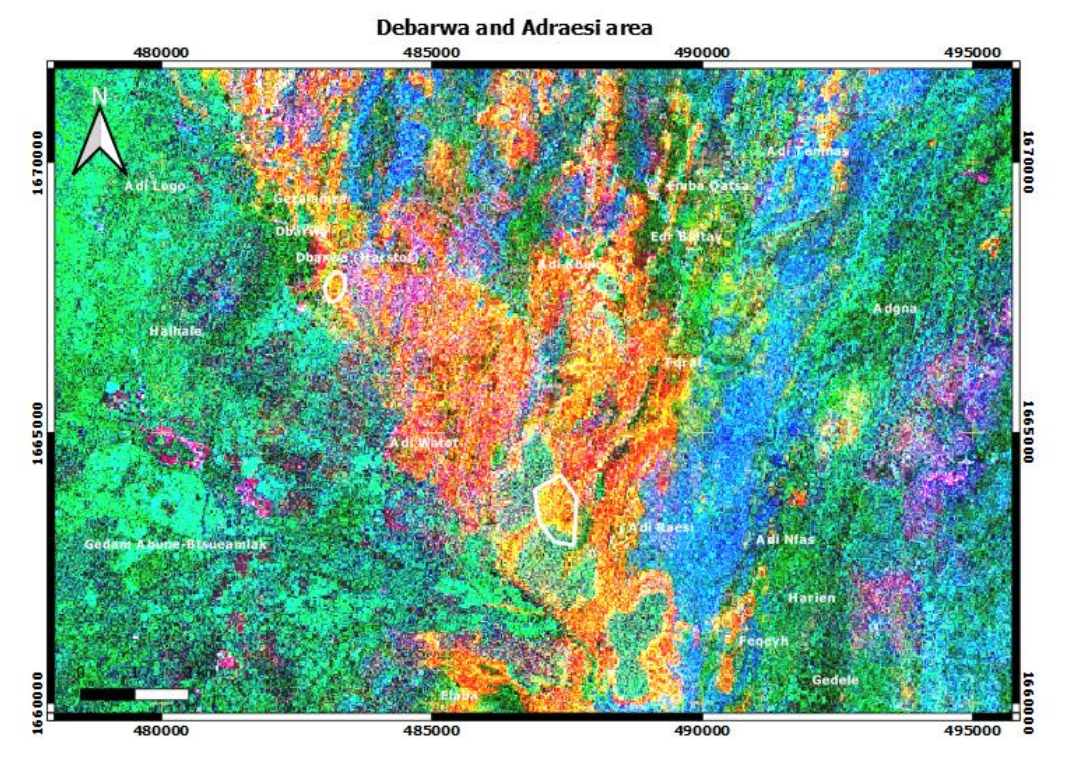


Emba Derho Aster image,
Sericite alteration band ration (4/6, 5/6, 5/8)

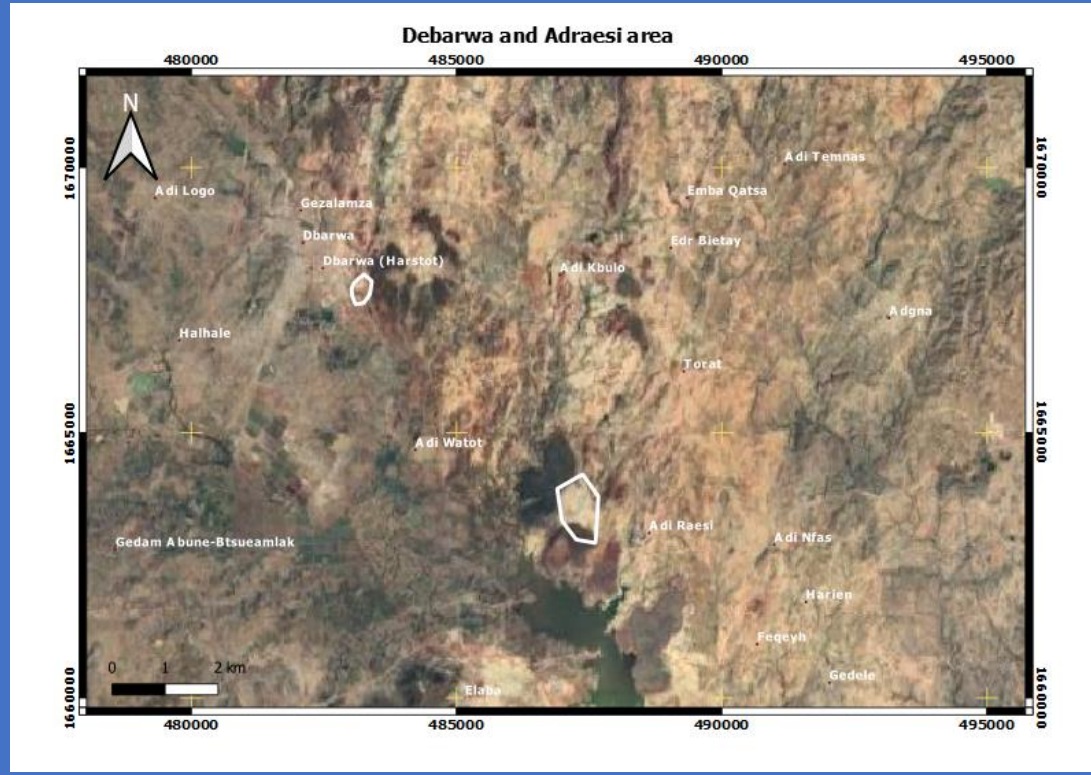


Emba Derho area Google earth image

2.10 Debarwa and Adrasi Mineralizations, Targets

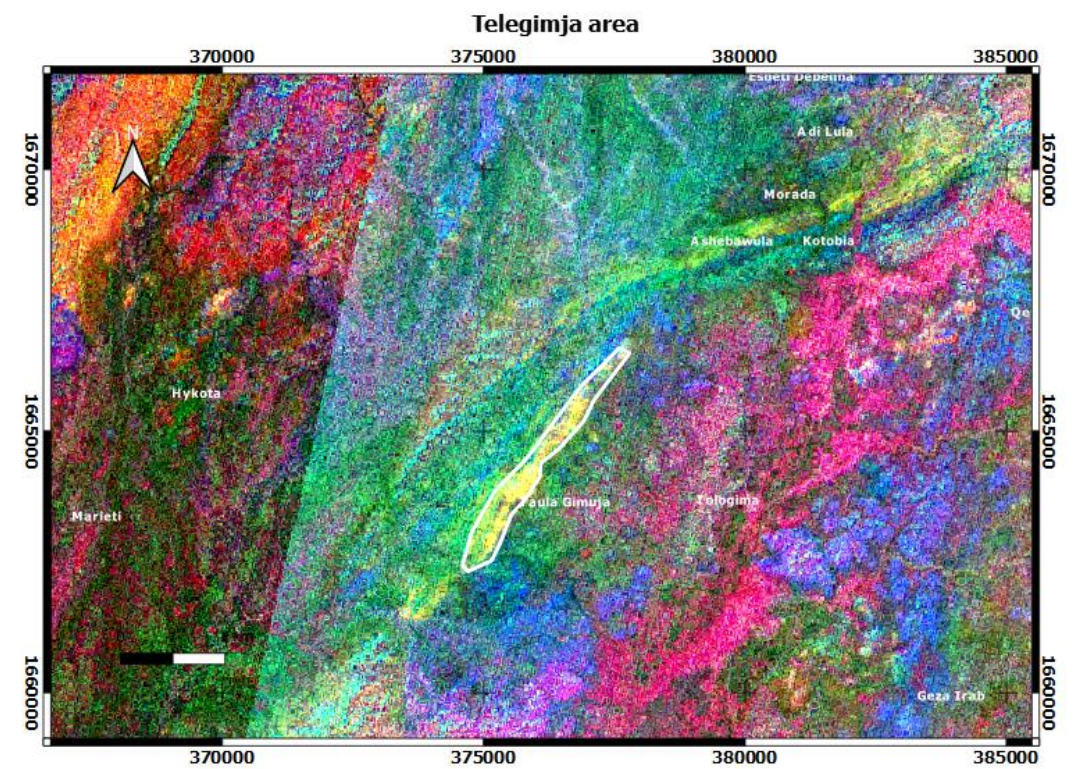


Debarwa and Adraesi Aster image,
Sericite alteration band ration (4/6, 5/6, 5/8)

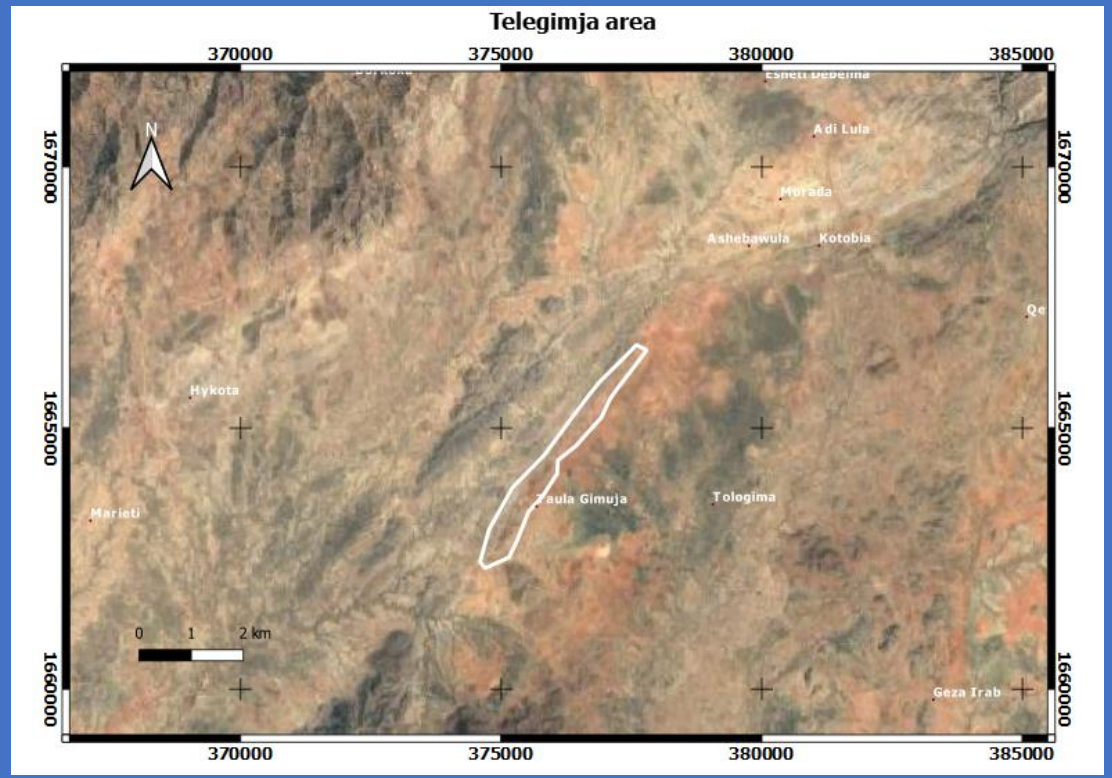


Debarwa and Adraesi Google earth image

2.11 Telegimja VMS mineralization target

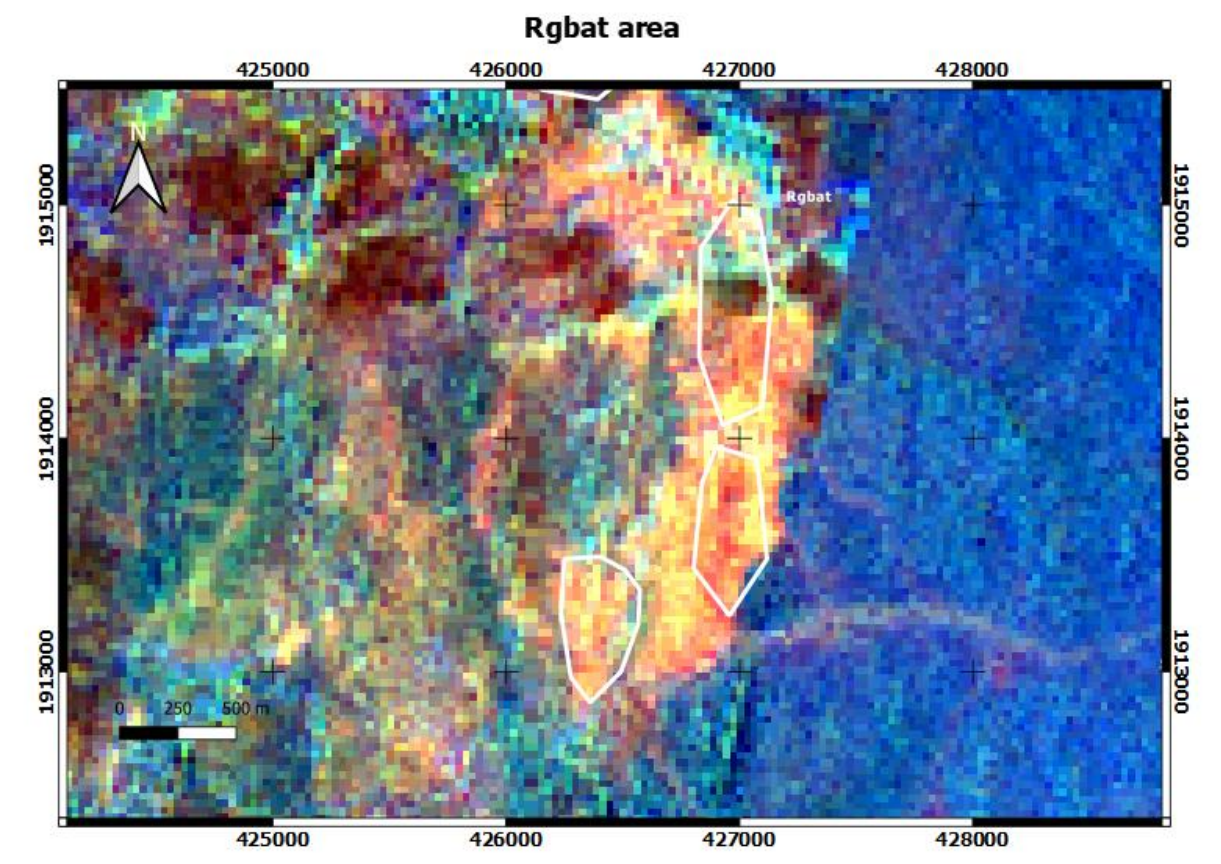


Telegimja sericite alteration zone

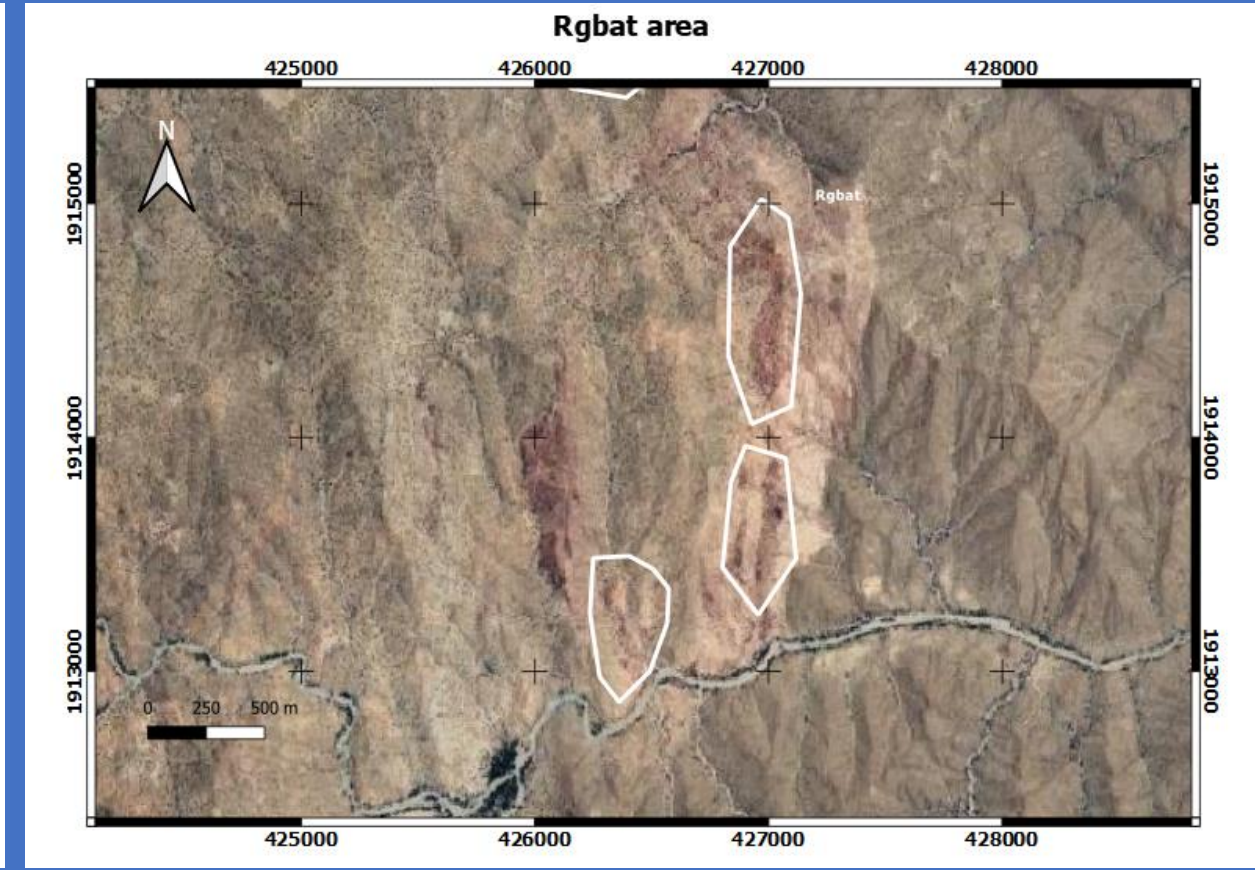


Telegimja Google earth image

2.12 Northern Eritrea Sericite alteration and Fe-oxide signatures



Rgbat Area band rationing (4/6, 5/6, 5/8)



Rgbat Area google earthimage indicating Fe-oxide sgnatures

3.0 Conclusion

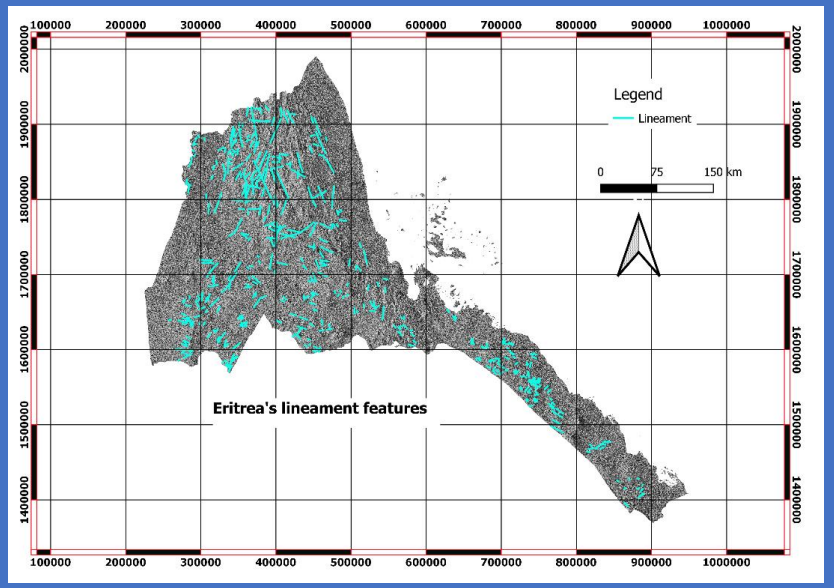
- **Aster image Band rationing (4/6, 5/6, 5/8) is meant for porphyry copper, in addition to that it is best for VMS targets as it has identified the Bisha and other mineral occurrences (gossans).**
- **Aster image Band RGB(631) is very helpful to identify the hematite alteration zones, in case of Bisha's gossan outcrops it provides valuable information and it delineates the alteration zones including the disseminated Fe-Oxide bearing outcrops.**
- **According to some publications green represents the sericite or smectite but in the case of Eritrea, mainly in the central part and southeastern part of the country green color lies on the tertiary basalts so the ratio band 5/6 is for an intermediate composition, chlorites or epidot alterations to mafic composition.**

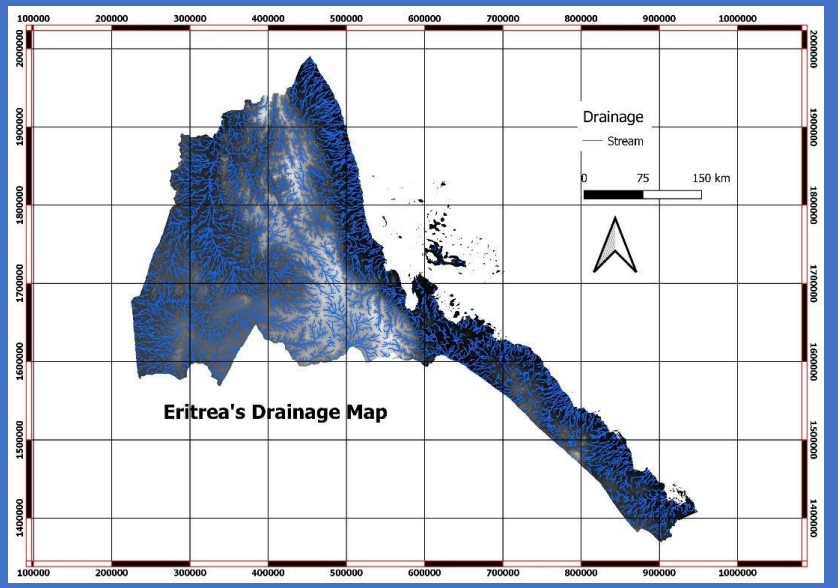
3.1 Acknowledgment

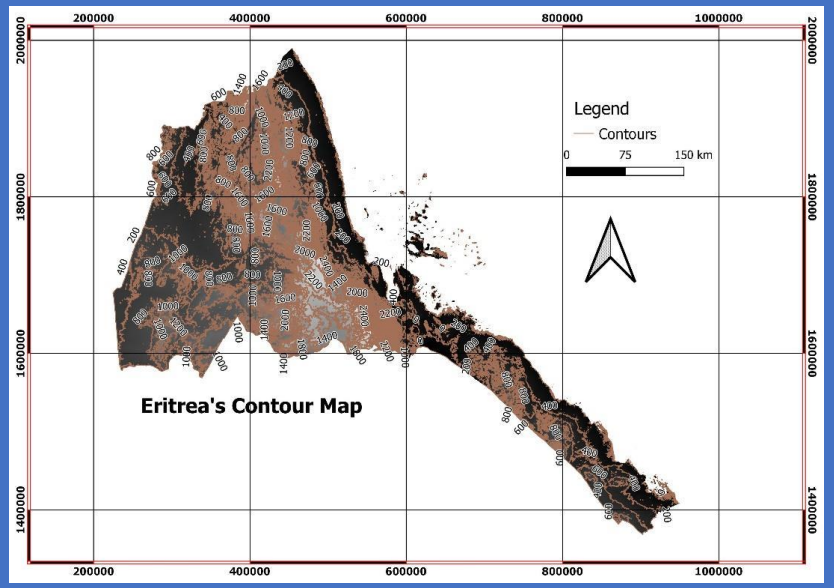
- Japan International cooperation Agency (JICA)
- Japan international cooperation Center (JICE)
- Japan Space Systems (JSS)
- Shimane University, Faculty of Natural Science and Technology
- JOGMEG of the East African desk
- Embassy of the state of Eritrea to Japan
- Ministry of Energy and Mines (MoEM), The State of Eritrea

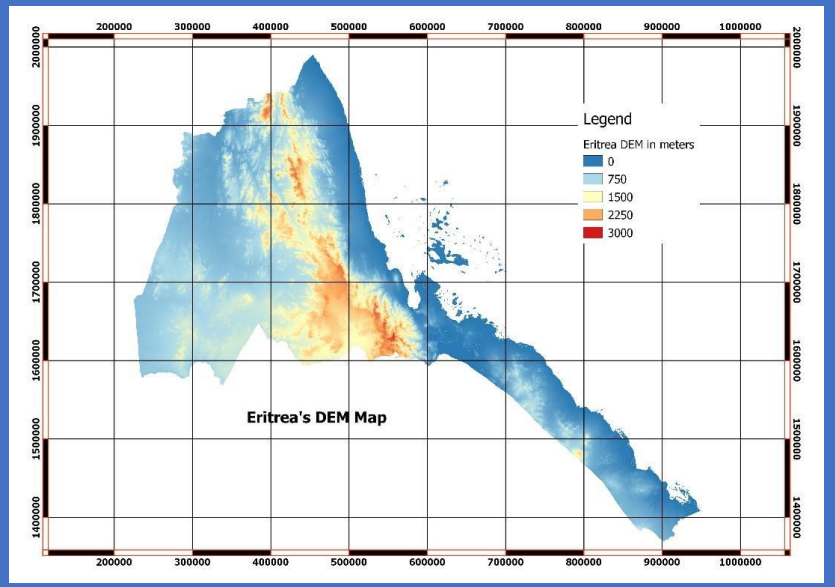
Arigatogozaimasu

QGIS DEM data analysis

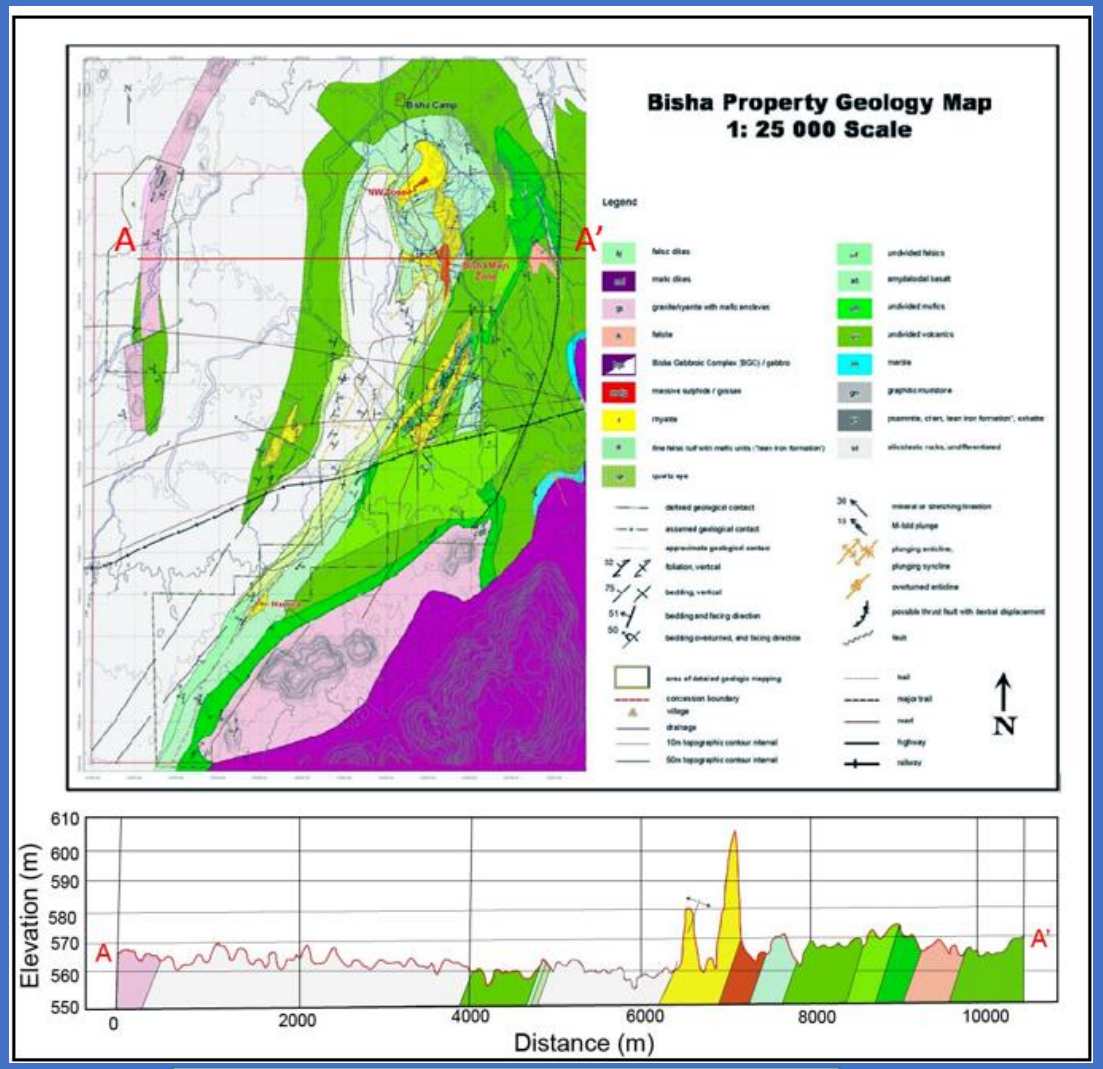




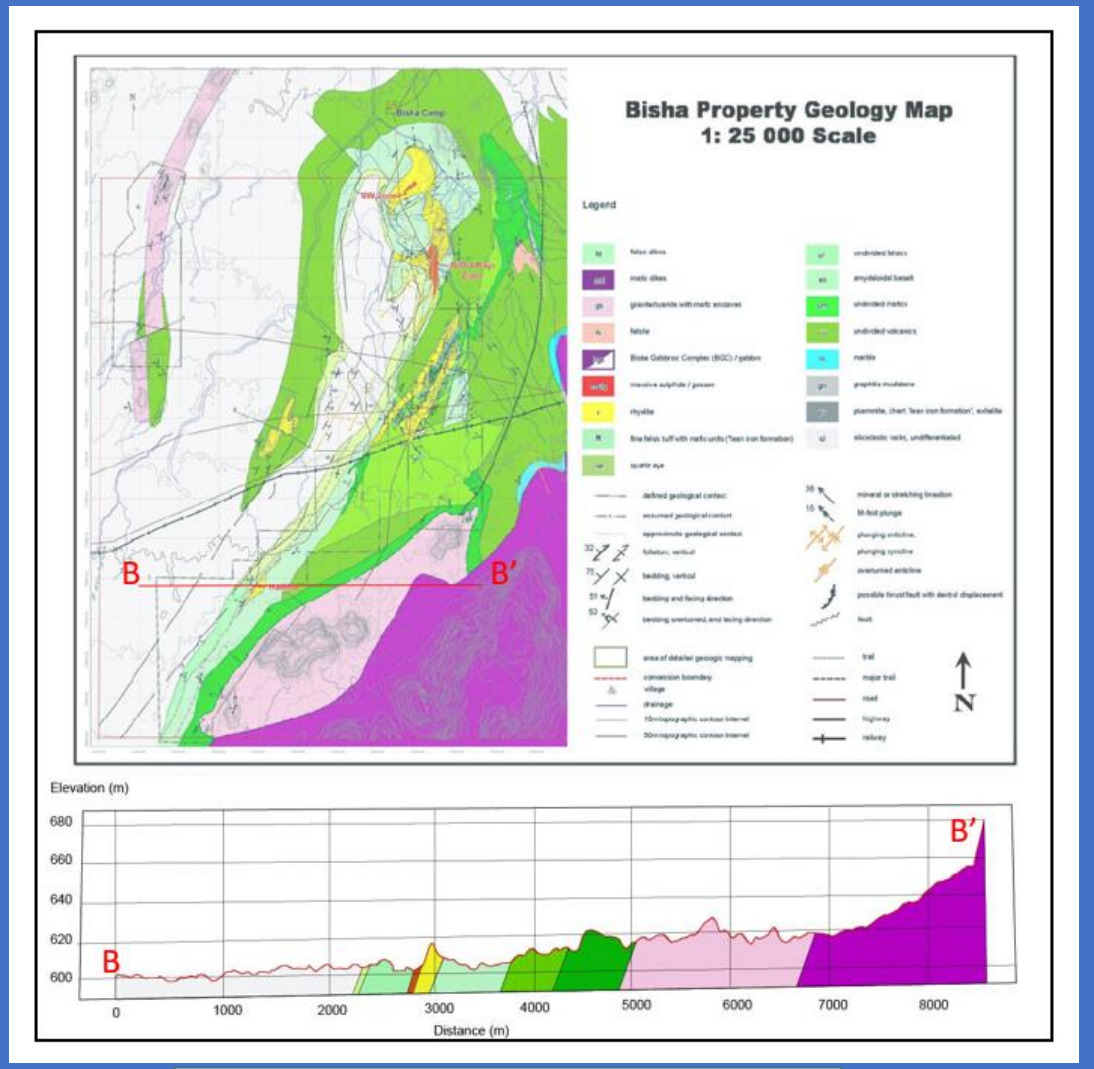




Bisha Main cross-section



Bisha Main Cross section



Harena Cross section